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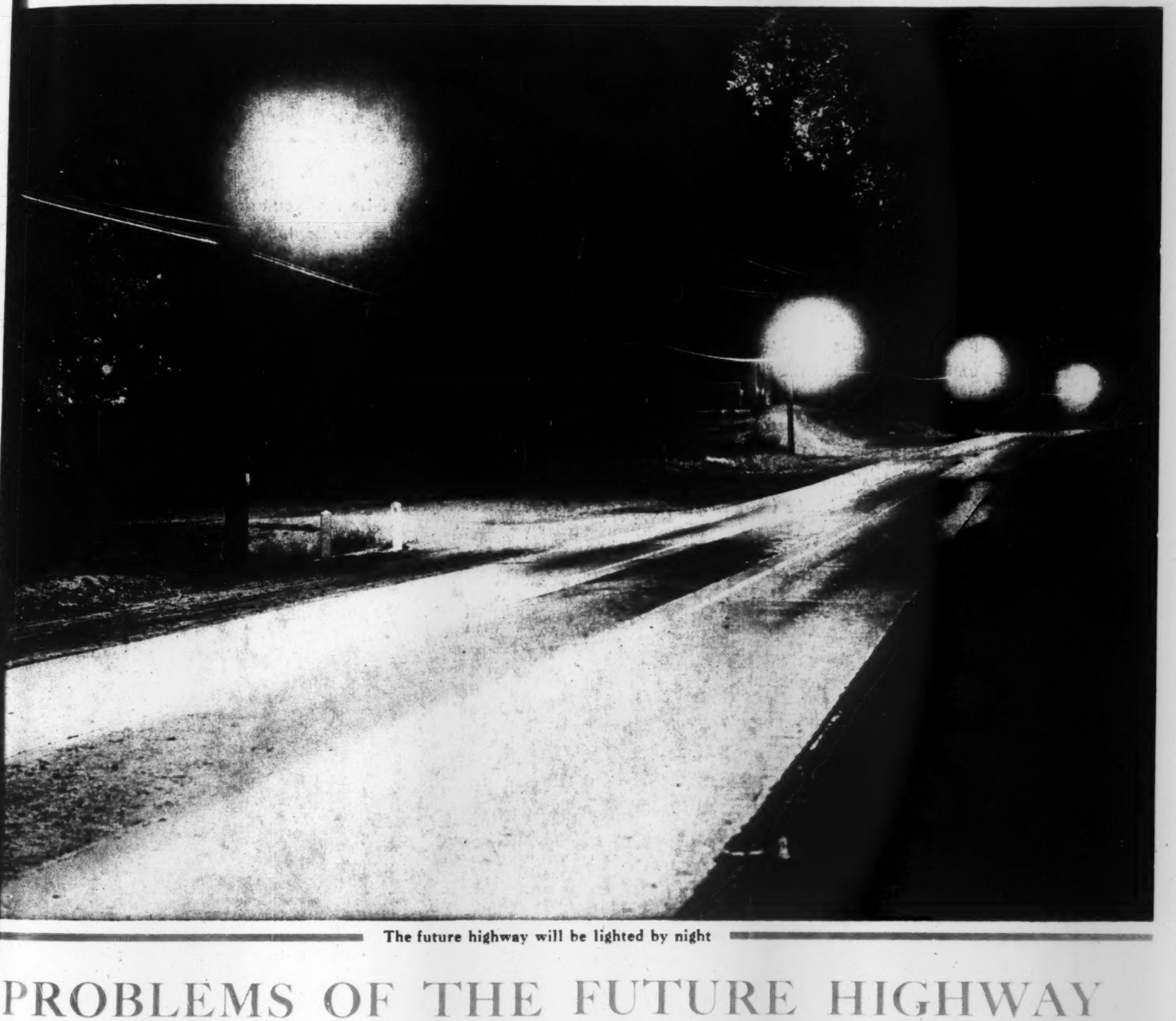
*January 17, 1935*

JAN 19 1935

# Engineering News-Record



The future highway will be lighted by night

# PROBLEMS OF THE FUTURE HIGHWAY

*A study of planning and design of road structures*

**FRANK T. SHEETS** **C. H. PURCELL** **J. R. BURKEY** **MILLER McCLINTOCK**

**M. W. TORKELSON** **ROY W. CRUM** **E. W. JAMES** **BERNARD E. GRAY**

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### A MOMENT WITH THE PUBLISHERS

# For Business Sense in Highway Policy—II

*(Continued from last week)*

LAST week this page pointed out that in their efforts to balance their budgets many public officials have abandoned the sound policies that have helped to develop highway transport and that they now commend to the power utilities. Today they are exploiting motor transportation as a convenient source of revenue for general uses. As might be expected the effect of this is to increase the cost of motor operation without respect to reason or equity.

But that it not all. While they impose excessive taxes upon registration, gasoline, tires, cars and other accessories, they cut to the bone the investment in highway betterment and allow wear and tear to take a sorry toll of existing roads. In other words, they submit highway transport to double taxation: a direct cash levy for general uses, which is, therefore, an arbitrary assessment rather than a service charge and in addition, an indirect, but none the less burdensome tax, in the form of higher operating costs that must be paid by every highway user through increasing wear and tear on his car, waste of fuel, lost time and greater hazard.

Thus government not only short changes the highway user by misusing the taxes he pays to maintain highway service; it penalizes also, through special taxation, every industry that serves motor transportation, every motorist and other highway user. Such a double handicap throttles highway transport and sacrifices the interests of every industry, every business enterprise, every motorist, every farmer and every other individual whose incomes are dependent on motor transportation.

Because of the extreme functional subdivision of highway transport noted in last week's discussion, these effects may not be obvious to each of those affected but, none the less, they are taking their toll; daily they fasten upon highway transport evils that eventually will strike home to it with devastating force.

All this, of course, is quite contrary to the principles now urged by public officials upon the utility operators. Is it not in order, then, to suggest that their counsel would come with better grace and more convincing force if these officials would first apply their ideas to the one utility in which so many governments—federal, state and local—now exert so important an influence? Is it unreasonable to suggest, in accordance with those principles, that government (1) establish registration fees and gasoline taxes at levels that will insure reasonable contribution by highway users to an adequate program of highway improvement and maintenance, (2) use these revenues exclusively for the purpose for which they have been collected and (3) desist from levying upon highway users special class taxes for general expenses which should be met by general taxation.

In some regions the increasing burdens thus imposed upon motor transport already have been reflected in decreased registration and use of motor cars. None can compute exactly what this means in ever-widening circles of unemployment, declining business and vanishing profits for the affected businesses and trades, to say nothing of the social and economic values sacrificed by motorists and other highway users. But although these losses cannot be consolidated on the financial statements of a few corporations, they are none the less substantial; and although the unemployment and distress are widely distributed amongst many individuals, small industries and businesses, they are none the less heavy and oppressive to each of them.

Some of the public officials responsible for these policies throw fits at the idea of a general sales tax because, they say, it tends to curtail consumption. Or else they burn with indignation that utility rates should be so high as to restrict volume. Suppose they are right. Then when will they see that in pyramiding on highway transport a series of cumulative sales taxes and in arbitrarily increasing the unit cost of motor-car operation, they are curtailing the economical use of the highways, thereby gouging the motor-using public and throwing thousands out of work?

Or, on the other hand, suppose that their supertaxation of highway transport is justified. May we not expect, then, that once in the power business, they will soak the power user as they now soak the highway user in order to balance their general budgets? Certainly their present handling of highway revenues does not strengthen their appeal for a hand in the power business. If the present administration of highway taxation, revenues and expenditures is a fair sample of public management and if every power user comes to know what every highway user knows, there will be scant enthusiasm for government in the power business.

Willard Chevalier

ENGINEERING NEWS-RECORD

Published every Thursday. Vol. 114, No. 3. Price 25c. per copy. Subscription, domestic, Mexico, Central and South American countries, $5 per year. Canada, including duty, $7.50. All other countries, $9 a year or 36 shillings. Entered as second-class matter April 11, 1917, at the Post Office at New York, N. Y., under the Act of March 3, 1879. Printed in U.S.A. Cable Address "McGrawhill, New York." Member A.B.P. Member A.B.C. Copyright 1935 by

McGRAW-HILL PUBLISHING COMPANY, INC., 330 WEST 42d STREET, NEW YORK, N. Y.

Editorial and Publishing Offices: 330 West 42d Street, New York; 520 North Michigan Avenue, Chicago; 883 Mission Street, San Francisco; Aldwych House, London, W. C. 2, England. Branch Offices: Washington; Philadelphia; Cleveland; Detroit; St. Louis; Boston; Greenville, S. C.

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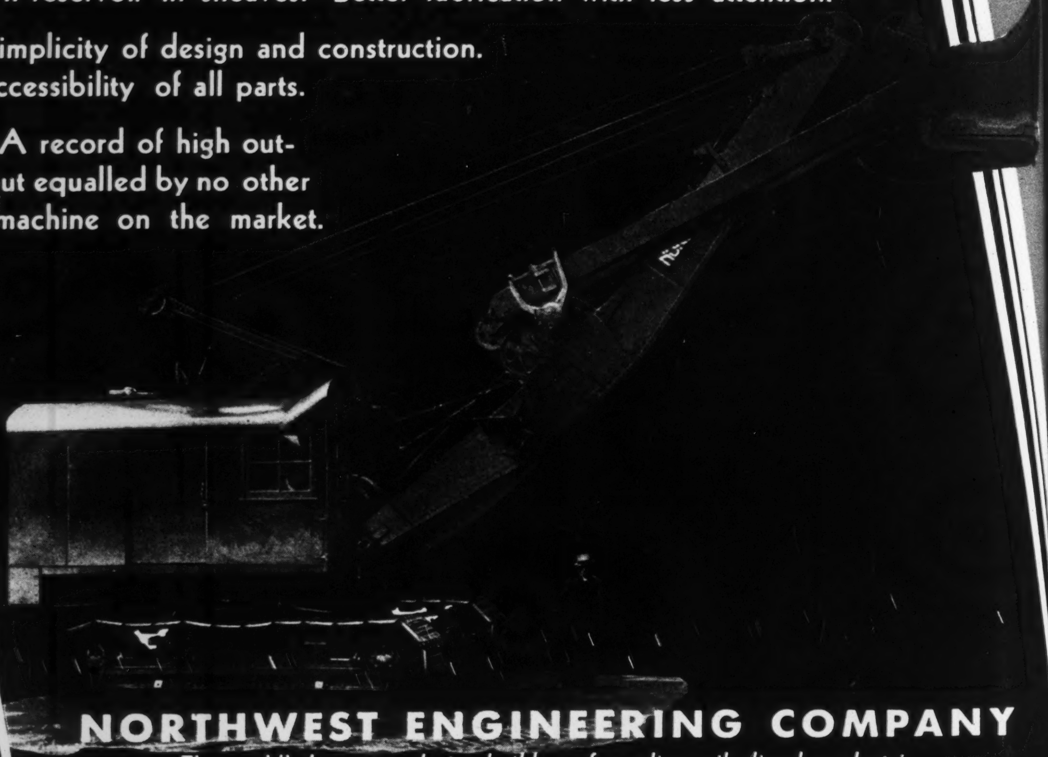

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## In the News:

THE GOVERNMENT is seeking supreme court action to stop Arizona from interfering further with Parker Dam construction work.

THE TREASURY DEPARTMENT has filed an application for $3,780,000 of PWA financing to build a power plant in New York City to serve government buildings.

THREE additional sections of the National Resources Board report on land use, minerals and mapping have been released.

WARNINGS of the approach of usual spring floods are contained in reports of swollen streams and menacing high water in the rivers from New York to Montreal.

FIRST LAND purchases have been made by the PWA in the $25,000,000 slum clearance and low-cost housing development in New York City.

PRELIMINARY WORK on tree planting in the proposed shelter-belt project may be started in the spring. Forest officials hope to secure funds from the forthcoming public-works appropriation.

COFFERDAM WORK has been started on the Grand Coulee project. The first steel sheetpile cofferdam will allow foundation work to extend from the west abutment to the low-water channel.

THE PROPOSAL of Chicago for an $8,600,000 island airport development in Lake Michigan has been turned down by the PWA following the report of a special committee that recommended against the project.

A CONTRACT has been awarded for constructing a new headquarters building for the Royal Canadian Mounted Police, in Ottawa, to cost $1,198,000, as part of the Canadian public-works program, outlined in *ENR*, Dec. 27, 1934, p. 821.

A PROTEST AGAINST the use of day labor in the coming public-works program has been sent to President Roosevelt by the Building Trades Employers Association of New York City.

## This Special Issue:

AMERICAN HIGHWAYS have reached a development stage from which the need of a long look ahead is indicated. If this is done, a promising view for improvement is opened up in two directions:

1. Long-time planning, financing and regulating road transportation systems.
2. Technical improvement of the highway as a structure designed and built to carry traffic safely and expeditiously as it increases in speed and in intensity.

One view presents a transportation development problem, and the other a strictly engineering design and construction problem. It is the latter probem that is considered in this issue.

A review of conditions indicates the need of such consideration. In its technical characteristics the modern road is the development of scarcely more than two decades. Ten years cover most of the more radical advances in design and construction. In these periods travel speeds have doubled, traffic intensities have multiplied several times, increasing freight traffic has brought heavier loads and longer vehicle units onto roads. Measured by the average of these demands, roads built ten years ago are inadequate; and measured by the maxima, they are definitely obsolete. These demands may be expected to increase—if not so greatly in maxima, certainly in spread over far greater mileages of road systems. Today's road design and construction must consider these possibilities.

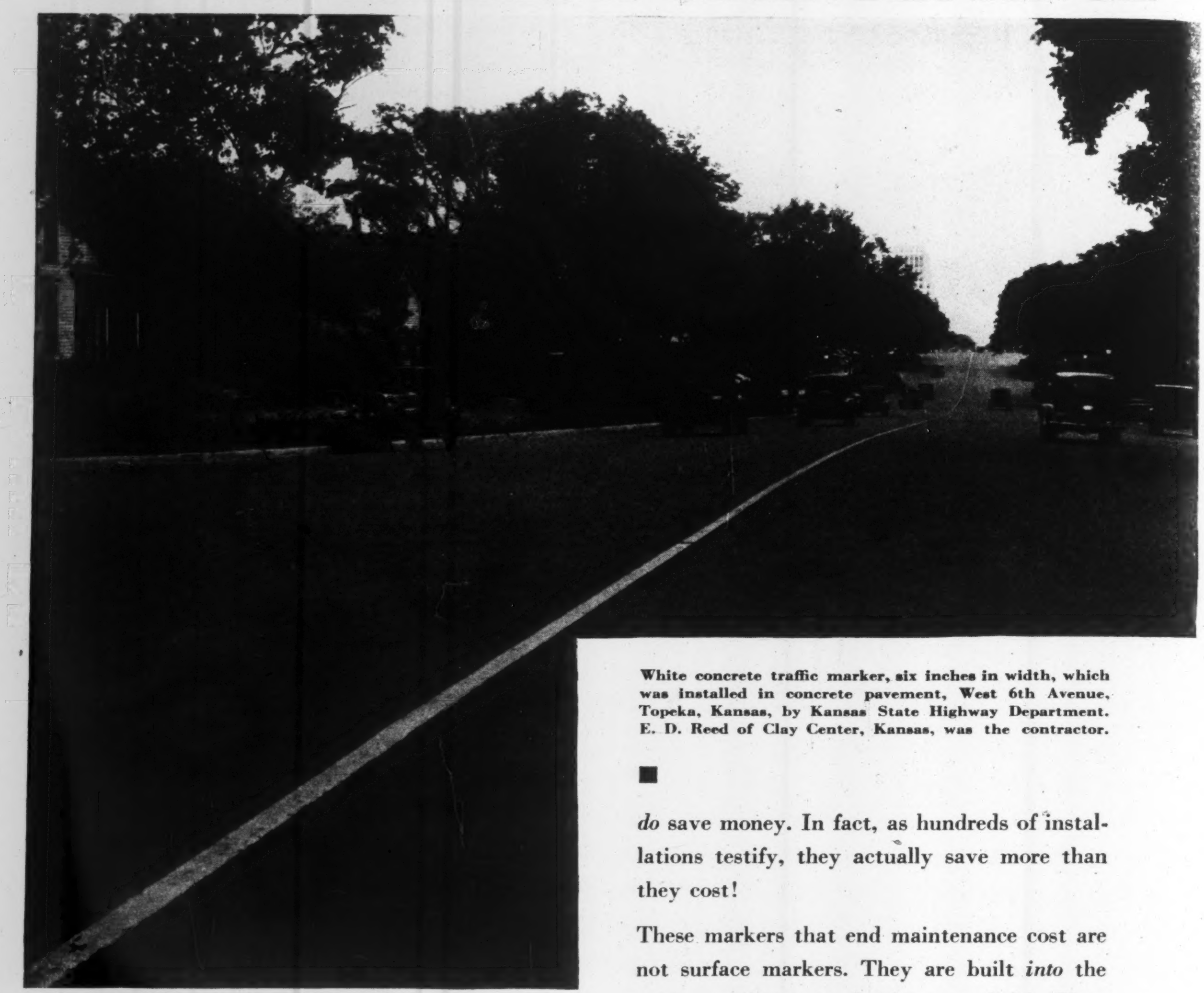
Along what lines should such consideration develop? It is the purpose of this issue to indicate the main possibilities and to discuss future design and construction as they may be forecast in general terms from present indications.

The discussion is presented in eight chapters written by eight consulting and contributing editors, each presenting a phase of the questions: (1) greater development and utilization of research; (2) closer tying of planning with traffic surveys and forecasts; (3) rerouting to curtail distances and escape congestion; (4) more liberal land taking for expansion of road structure; (5) roadway design for future traffic speeds and intensities, (6) elements promoting safety; (7) bridges in integral part of roadways; and (8) secondary roads for future requirements.

## Coming Articles:

SINCE LAST JULY driving operations on the San Jacinto tunnel—key bore of the Colorado aqueduct project—have been virtually at a standstill, from the Potrero shaft at the west end of the work, following the striking of a large flow of water which for months defied all efforts to pump out the 800-ft. shaft and dry up the heading. A description of this construction struggle will appear soon.

# *End* MARKER MAINTENANCE



**White concrete traffic marker, six inches in width, which was installed in concrete pavement, West 6th Avenue, Topeka, Kansas, by Kansas State Highway Department. E. D. Reed of Clay Center, Kansas, was the contractor.**

■

SAVING money on maintenance is not the only reason why white concrete traffic markers are installed. But it is the most important.

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# ENGINEERING NEWS-RECORD

January 17, 1935

*ANNUAL HIGHWAY NUMBER*

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## THE ROAD OF THE FUTURE

*. . . . A Foreword*

THESE are times of reappraisal and reorientation, in the field of highway construction as in other human service. The roadbuilder has performed his tasks excellently so far, but what of the future? Marvelous as are the changes in transport made possible by the creation of the modern highway system, demand is advancing so rapidly that it threatens to outdistance road progress unless we look intently to coming requirements. The works of today must serve the needs of the future or they will quickly become obsolete. And so, though he is often taxed to the utmost to satisfy immediate requirements, the true measure of the roadbuilder's planning and building is the future.

In the following pages, therefore, the road engineer is asked to forget the details of his momentary tasks and look on the problems of the highway with a prophetic mind. For these few hours he is to speculate on the future highway. What are to be its qualifications? What more must it possess of safety, strength, travel room and convenience and attractiveness to the road user? We are warned by today's deficiencies in all elements of the road built a decade ago that timidity in prediction is disastrous. Boldness offers fewer chances of failure.

It is of the road ten or fifteen years from 1935 that the road engineer is asked to think. This is, in fact, the road that he should be designing. If the roads laid down in the year now beginning are to have the acclaim of the road user when the half century has rolled around to 1950, then prophetic planning must be a vital element of the road designs now on the drawing tables.

To open ways for his mind to travel eight talented highway engineers, acting as contributing editors for this special number, have staked out paths to be explored. These open up broad territories of highway thought—fields of scientific research, route rectification, travel safety, roadside development, secondary-road service and the design of pavement and bridge structure.

The future road offers many problems. Two controlling factors pervade and dominate them all—a need for determined facts and an extension of highway engineering horizons. Whether in design, location, safety measures or traffic service, sound decision by the highway engineer is hampered by the lack of determined facts. Encouragement of research is a vital part of the engineering of the future highway.

Another essential element of his equipment is the development of a keener perception of the expanding boundaries of highway engineering. These are rapidly widening out into territories of economics, soil physics, and traffic trends and incidences. Roadway and bridge design are progressing beyond statics of structure into the dynamics of safety, travel freedom and appeal to enjoyment in the use of the road.

And now a word on the consulting editors. All that is forward-looking and of prophetic vision in the thirty-six pages that follow is their contribution. Their rank in constructive thought and leadership needs no proof beyond the roll of their names printed on this page. They have here created a vision of the vital importance of the engineering problems of the future highway. . . . . EDITOR

### ENGINEERING PROBLEMS OF THE FUTURE HIGHWAY

A symposium of special articles and discussions planned for the furtherance of efficient road development

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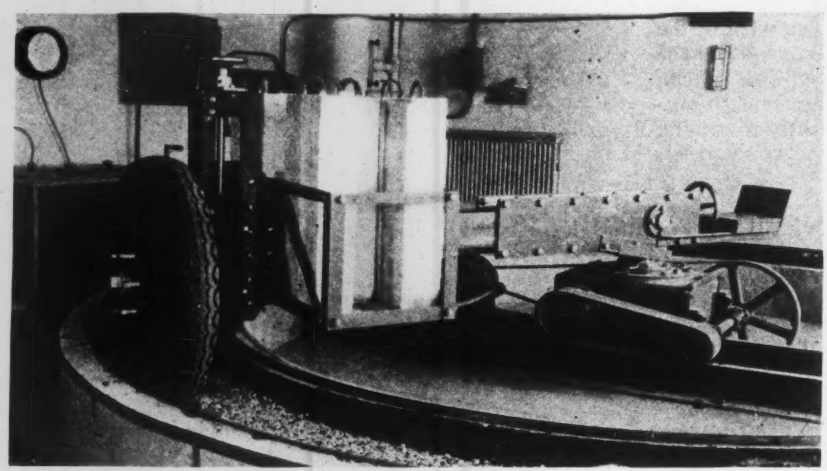
# 1...Highway Research

### *Roy W. Crum*

AN ADVANCE from experimentation, on which past highway development has depended, to investigation of scientific principles is called for in solving future road problems • Giving full credit to the value of the experimental work that has been accomplished, this discussion calls for a more active support of true research work and greater encouragement of research workers.

WE CAN justifiably prophesy that research will have a large part in the future development of highway engineering. Just what the fruits of the research will be is not so easily predictable, but that they will be plentiful is certain.



**CIRCULAR TRACK** for testing road-surfacing materials in the laboratory of the National Crushed Stone Association

The object of this chapter is to review the relation of research to past developments; to call attention to some of the approaching problems that need research attack and to point out wherein it is necessary for research workers and their programs to have the active interested support of highway administrators. It is intended that this will be a constructive argument for research as a definite, directed, purposeful element in the future highway program.

Roadbuilders have passed through a hectic time since the war. Continually changing traffic and transportation conditions forced them to build at high speed in anticipation of future service requirements that could be only vaguely foreseen. In this period research work consisted largely in attempting to keep up with the continuous procession of questions demanding immediate answers. Important problems have been so insistent that highway administrators have been forced to move before their technical staffs have had opportunity to carry their studies to completion. This means that at this time there are many problems before us for which the answers thus far in use are only partly complete.

Now that there is a prospect of a more stable and a less hasty era in roadbuilding, it is more important than ever for highway administrators to realize that the appropriation of a reasonable percentage of highway funds for research is not a living expense but an investment.

## Past progress sound

Nevertheless, in spite of the hurry-up atmosphere in which we had to work in the nineteen twenties, the results of sound technical research underlie much of the present-day practices. Only a few need be mentioned.

Since the pressing demand was for rain-proof surfacing, that part of the road received earliest attention. In fact, as engineers we slighted our own axiom that places first importance upon foundations; hence much of the early construction was found to be faulty on this account.

However, this situation was soon recognized, and since the middle of the period much progress has been made in discovering the engineering fundamentals of pavement foundations for rural roads. Soil characteristics of importance in road construction are now identifiable, and soils have been classified with respect to roadmaking properties.

As the results of research, concrete pavement slabs are designed according to rational theory, and concrete for all purposes is manufactured in accordance with definite scientific procedure. The proportions can be accurately designed for the strength required, and the predetermined result is assured by accurate measurement and correction for variations in materials.

In brick pavements more economical use of material has been brought about, and better material such as that produced by the de-airing process is now available. Recent work with fillers and cushion courses has been already reflected in improved methods of brick paving.

A vast amount of study has been devoted to the use in road work of oils, asphalts and tars. Since these complex materials are adapted to use under a great variety of conditions and to roads suitable for a wide range in traffic, they have provoked intensive study of their characteristic properties, so that now bituminous materials can be much more definitely chosen and secured for a specific condition of use. Principles of design of mixtures have evolved, and tests for the stability of sheet-asphalt mixtures have been devised.

For building roadbeds the research engineer has developed the fundamentals of drainage, culvert design and compaction of fills under adverse circumstances. And it goes almost without saying that the development of manufactured materials and knowledge of the properties of natural materials are to the credit of research.

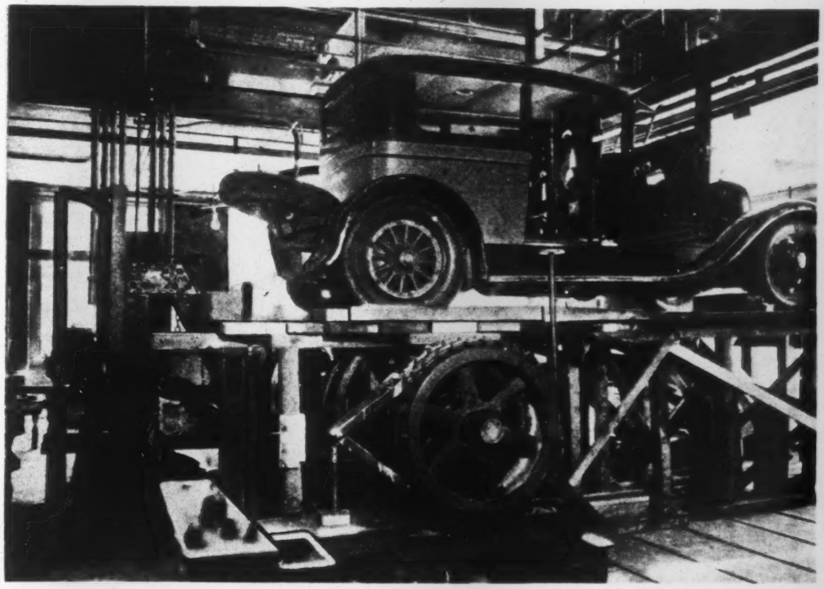
### Research problems ahead

But now we are more interested in the future. These examples from the past have merely been cited as authority for the prediction that research will be a great factor in the continued development of highways. In fact, as long as highway engineering is alive and growing it will attract men of imagination and inquiring minds who cannot be stopped from searching for new knowledge. This is a priceless asset that should be cultivated and helped to expand.

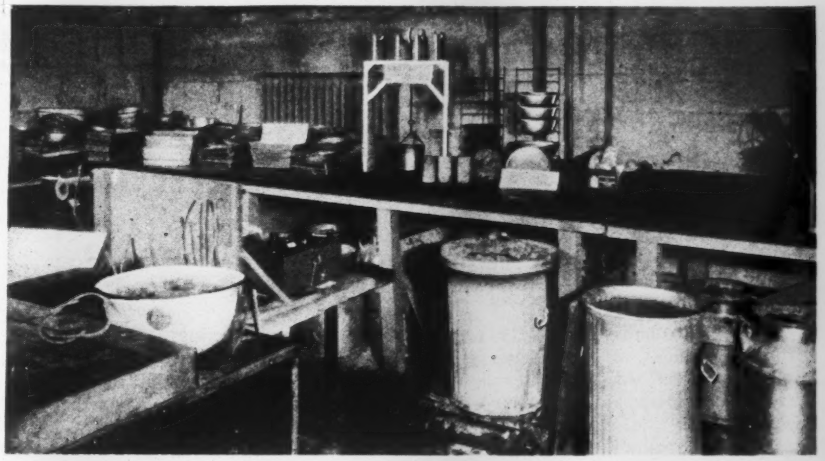
What of the problems before us? If we stop to think how, only a few years back, the commonplaces of today's highway transportation were yet unknown, we will realize the impossibility of predicting the future. Nevertheless we can at least feel sure that we will go on for many years developing more and more satisfactory highway transportation facilities. Research into things now unthought of will be a potent factor. Although in this direction we cannot plan for a research program, we can plan to find and develop men who will discover new things and to provide opportunities for them to carry on. The time is certainly at hand when research directed toward the discovery of fundamental principles, even without the prospect of immediate utilization, should be provided for and encouraged along with that carried on for the solution of problems immediately before us. Research is fundamentally the searching out of new information, and all new information is important, whether it answers a known question or is entirely unexpected.

A long list of desirable and important highway research problems could be easily compiled. However, that is not the function of this article. It is interesting to note though that such a list would be for the most part almost identical with a list of five or ten years ago. This does not mean that nothing has been done. It merely goes to show that under the changing conditions that must be met, final solution of any of the problems is reached very slowly.

Most discoveries come about as a result of a start along some specific line. Even a most imaginative research worker must have a starting point and some idea of his destination, even though he may be beguiled en route into following an inviting bypass. So it may be appropriate in this place to mention some of the large problems that we know are confronting us now.



**CALIBRATING AUTOMOBILE** (gas-electric drive) for measuring tractive resistance at Iowa State College engineering experiment station.



**FREEZING AND THAWING** test apparatus in the laboratories of the University of Minnesota.

*Human Safety*—The loss of life on American highways is so appalling that its challenge cannot be ignored in the smallest degree. Although it may be that faulty human nature is far more responsible than faulty roads, still unremitting endeavor to build the maximum of safety into the roads is distinctly the responsibility of the engineering profession. To this end, constant study of the causes of highway accidents, with a view to discovering every possible way to prevent the road from contributing to casualties, is research work that must be prosecuted in every street and road jurisdiction. For instance, we know that slipperiness is a common hazard, and recently methods for measuring the relative slipperiness of different surfaces have been devised. Now comes the problem of so building the surfaces that even reckless drivers will have some protection against themselves.

Pavement width, arrangement of traffic lanes, design of intersections, degree of curvature, vertical and horizontal sight distance and superelevation are all factors in the safety problem that require further intensive study.

*Durability*—The factors that influence the durability of pavements and other highway structures are only imperfectly understood. The effects of natural forces and of speed, weight and type of vehicle must be studied and ways found to overcome adverse conditions. Data concerning the effects of these factors upon the probable service lives of the different highway units are needed as prerequisites for improvements and as bases for equitable taxation and for study of other problems in highway transportation economics.

This work is going forward. In the laboratories of several engineering colleges and highway departments, studies of the effects of frost and other natural phenomena on materials and combinations of materials are being made. A need for the future is to relate the laboratory phenomena observed to the behavior of structures over a period of years. Accelerated methods of test for durability against natural forces are gradually evolving.

**SAWING PAVEMENT SLABS** into test specimens at the laboratories of the Iowa highway commission.

*Pavement Foundations* — As previously mentioned, rapid progress has been made in the study of subgrade soil characteristics, and some progress has been made in the application of soil science to roadbuilding. But this science, which is only in its infancy, is fundamentally important to all types and classes of roads, and little further progress in road surfaces can be expected until the effects of subgrade soil characteristics and treatments are more completely disclosed. The relation of subgrade soil to the strength and durability of rigid-slab pavements must be different than it is to flexible bituminous surfaces or to simple soil treatments, but of these exact relationships we are as yet ignorant.

*Bituminous Surfaces*—During the last fourteen years almost countless combinations of bituminous materials and aggregates under equally numerous construction methods have been tried and described in technical literature. Many have been successful, but some have not. Present-day practice in this field has been largely the result of trial and error. Methods developed in this way may, of course, be very satisfactory, especially in the particular locality where developed, but the process does not tell why they are satisfactory or what will be the effects of varying conditions. For a more satisfactory basis for future practice, more research into the whys and wherefores of the behavior of these materials is a distinct need.

A new line of attack on this problem has recently been started. The circular test tracks now being used in several laboratories have proved their worth as a means of quickly studying the effects of traffic upon different combinations of material under varying conditions. This equipment, although particularly adapted to the study of bituminous mixtures, is applicable to the study of any type of road surface.

*Relation of Highway Design to Transportation Economics*—During the period of the rapid increase in the number of motor vehicles in use, the demand for road improvement was so great and the need so urgent that roadbuilders had difficulty in keeping pace with the large appropriations made for roadbuilding purposes. The demand, in which everyone joined, was sufficient justification. Now, however, with highway use as a whole more stable, the very large problem presents itself of continuing the development of highway systems along sound economic lines. An important feature of this problem is the relation of the design of the highway itself to economic factors. Its effects upon annual cost of highway service, upon cost of vehicle operation and upon adequacy of service are in need of exhaustive studies.

Inquiries into these matters are proceeding, but the importance of research in this particular field is not yet sufficiently realized by highway administrators. Nevertheless, notable work has been done and is under way on such problems as effects of grade and alignment upon costs, fundamental tractive resistance and depreciation of highway units.

*Earth Roads*—Since as far back as 1920 forward-looking highway engineers have realized that sooner or later they would have to tackle the difficult problem of the improvement of the thousands of miles of land-service and other light-traffic roads. The difficulty of this problem may be realized from the fact that these roads constitute some 90 per cent of the total mileage, and that whatever is done to improve them must necessarily be on very little money per mile. Although this problem has always been present, the need for the building of high-type roads on heavy-traffic routes as a backbone highway system was so predominant that this problem was for many years shoved into the background. Now it is coming to the front and must be faced. The wellbeing of the country in general and the continued development of highway transportation demand attention to this problem. It is fascinating because the possibilities for far-reaching effects by some new discovery are enormous.

Research men have not been entirely idle in this respect. Very useful and valuable methods have been devised, but still most of those that have demonstrated their worth lie in the range of at least moderate cost. There is, indeed, a great sphere of usefulness for moderate-cost roads, but the greatest unexplored region is that of really low-cost improvements. Progress in this field must be made, for the most part, through governmental agencies. Until the discoveries are made there is nothing to attract the financial support of commercial agencies as there has been in the development of the use of such materials as tar, asphalt, cement and brick, for no one knows now what the useful materials will turn out to be.

The discoveries (from research work) that have led to the so-called stabilized roads, in which the stability achieved by means of favorable combinations of earth, sand, clay, gravel, stone, etc., is conserved by chemical treatment, constitute the most notable recent progress.

Still in their infancy, roads of this type offer great promise of future economic benefit if research is continued.

## Available facilities for research

The potential facilities for highway research in the United States and their possibilities for benefiting highway transportation are huge.

The federal agencies, including the U. S. Bureau of Public Roads and the National Bureau of Standards, the highway departments of the 48 states and the District of Columbia, the highway departments of 124 engineering colleges and the research departments

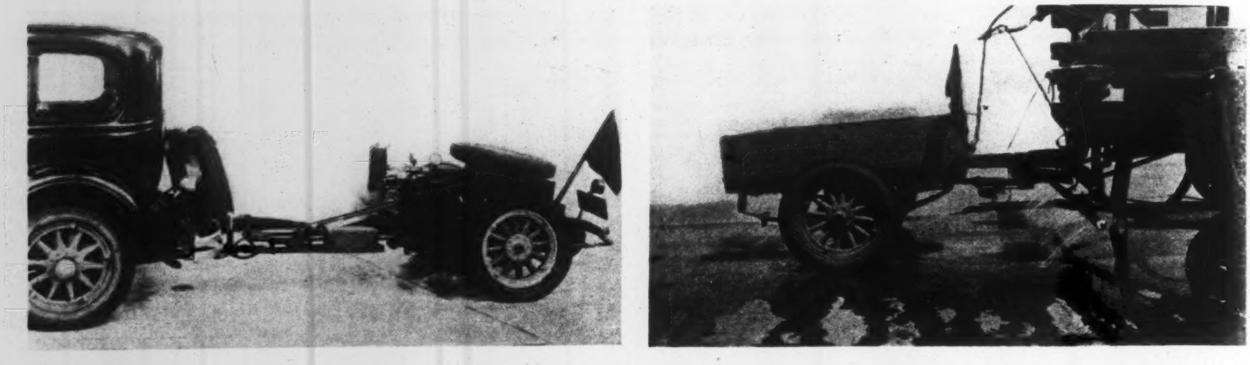
## PRESENT STATUS OF SUBGRADE INVESTIGATIONS IN HIGHWAY DEPARTMENTS

Compiled by Subcommittee on Subgrades, Committee on Materials, American Association of State Highway Officials

| | State | Questioned | Replied | Contact with B. P. R. soils lab. | Investigations Conducted by | | | | | | | | | | | | | Use of Data in Design and Construction | | | | | | | | Principal Value of Subgrade Investigations and Special Problems Requiring Investigation and Treatment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Laboratory Organization | | | | | | Field Organization | | | Resident Engineer | | | | | | | | | | | | |
| | | | | | Mechanical Analysis | Plasticity Tests | Cent.-Moist Equivalent | Field-Moist. Equivalent | Volumetric Shrinkage | Linear Shrinkage | Selection of Samples | Bur. Pub. Rds. Field-Survey Procedure | Bur. Chem. & Soils Meth. of Field Classification | Visual | Special Investigation | General Information | Corrective Treatment Applied to Local Conditions | Selection of Soils for Fills or Subgrade Treatment | Selection of Materials for Low-Cost Road Construction | Designs Prepared to Meet Typical Soil Conditions | Information Placed on Prelim. Plans for Guidance of Designer | Report and Recommendations, to Designer on All Projects | Report and Recommendations, to Designer on Part of Projects | |
| 1 | Ala. | X | X | X | X | | | | | | X | | | X | X | X | X | X | X | | X | | X | Subgrade treatment; sand-clay, top soil, clay gravel and chert for bases. |
| 2 | Ariz. | X | X | | X | X | X | X | X | X | X | | | | X | X | | X | X | X | | X | | Oiled roads |
| 3 | Ark. | X | X | X | X | X | | X | X | | X | | | | X | | | | X | | X | | X | Base courses for low-cost construc. Fill subsidence and flow |
| 4 | Calif. | X | X | X | X | X | | X | | X | X | X | X | X | X | X | X | X | X | X | X | X | | Excessive shrinkage and low support in certain soils. Frost boils |
| 5 | Colo. | X | X | | | | | | | | | | | X | | | X | | | | | | | Erosion in fills of fine sands. |
| 6 | Conn. | X | X | | X | X | X | X | X | | | | | X | | | X | | | | | | X | Settlement and volumetric changes in fills. |
| 7 | Del. | X | X | | | | | | | | | | | | | | | | | | | | | |
| 8 | Fla. | X | X | X | X | X | X | X | X | | X | X | | | | | X | X | X | | X | | X | Admixtures to improve heavy clay subgrades, when clay content exceeds 30% bitum. road-mix sand. |
| 9 | Ga. | X | X | | X | | | | | | X | | | | | | X | | X | | | | X | Low-cost road construction. Excavation and backfill at soft spots. |
| 10 | Idaho | X | X | [1] X | | | | | | | | | | X | | | X | | | | | | | Sub-bases and drainage. |
| 11 | Ill. | X | X | | X | X | | | | | X | X | X | X | X | | X | | X | | X | | X | Compaction of subgrade. Low-cost road construction. |
| 12 | Ind. | X | X | X | X | X | | | | | X | | | | | X | | | X | | | | | Construction of stabilized roads: CaCl$_2$, rock salt asphalt emulsion. |
| 13 | Iowa | X | X | | X | X | X | X | X | X | X | | | | | X | | | X | | | | | Stabilization of subgrades under gravel and oil-treated gravel surfaces. The prevention of frost boils. |
| 14 | Kan. | X | X | X | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | | Extensive investigations. Data not yet correlated. Warping of concrete pavements. |
| 15 | Ky. | X | | | | | | | | | | | | | | | | | | | | | | |
| 16 | La. | X | X | | X | X | | | | | X | | | X | | | X | | | | | | | Base courses for surf. treatment; fills. |
| 17 | Me. | X | X | | | | | | | | | | | X | | | X | | | | | | | Sub-bases employed at weak spots. |
| 18 | Md. | X | X | X | X | X | | X | X | | X | X | | | | X | X | | X | | | | X | |
| 19 | Mass. | X | X | | | | | | | | | | X | | | X | | | | | | | | Shrinkage factor of certain soils being investigated. |
| 20 | Mich. | X | X | X | | X | | | X | | X | | X | | | | X | X | X | X | | X | | Frost heaving. Construction of fills in peat marshes and on solid ground. |
| 21 | Minn. | X | X | X | X | X | X | X | X | | X | X | X | | | | X | X | X | X | | | X | Frost heaving. Crack control. Bases for bituminous surfaces. Stabilized gravel surfaces. |
| 22 | Miss. | X | X | X | X | X | X | X | X | | X | | | X | X | X | X | X | X | | X | | X | Selected material placed in top 2 ft. of grade. Base courses. |
| 23 | Mo. | X | X | X | X | X | | X | X | | | X | | | | X | X | X | X | | | | X | Nature and influence of binder in traffic-bound roads. Condition surveys of constructed fills. Jetting of fills. |
| 24 | Mont. | X | X | | | | | | | | | | | X | | | X | | | | | | | Sub-bases employed at weak spots. |
| 25 | Neb. | X | X | | (2) | | | | | | X | | | | | X | | | X | | | | | Classification of soils. Final volume-weight in fills. Control of bituminous mat surfaces. |
| 26 | Nev. | X | X | | | | | X | | X | X | | | | | | | X | | | X | | | Field-moisture equivalent and linear shrinkage used as criteria. |
| 27 | N. H. | X | X | X | X | X | X | X | X | | | X | | | | X | X | X | | X | X | X | | Frost heaving and sub-base design. |
| 28 | N. J. | X | X | | | | | | | | | | | X | | | X | | | | | | | Drainage and supporting power. |
| 29 | N. M. | X | X | | X | | | X | | X | X | | | | | | X | X | | | | | | Require mixing and placing or "plating" in fill construction. Desire measure for degree of compaction required in subgrades for pavements |
| 30 | N. Y. | X | X | | | | | | | | | | | | | | | | | | | | | |
| 31 | N. C. | X | X | X | X | X | | X | X | | X | | | | X | | X | | X | | | | X | Stage construction. Failures repaired |
| 32 | N. D. | X | X | | X | X | | X | | X | | | | | | | X | | X | | X | | X | Design of low-cost roads. |
| 33 | Ohio | X | X | X | X | X | X | X | X | | X | | | | | X | X | | X | | | | | Stabilis. of soils for low-cost roads. |
| 34 | Okla. | X | X | | | X | X | X | X | | X | | | X | X | | X | X | | X | X | | X | Sub-base employed on bad soils. |
| 35 | Ore. | X | X | | | | | | | | | | | | | | | | | | | | | |
| 36 | Penn. | X | X | X | X | X | X | X | X | | | X | | | | | | X | X | | | | | Stabilization of soils for low-cost roads. |
| 37 | R. I. | X | X | X | X | X | X | X | X | | | | | | X | | | | | | X | | | Sub-base design. Improvement of failures on reconstruction. |
| 38 | S. C. | X | X | | X | | | | | | X | | | X | | | X | X | X | | | | X | Low-cost road constr.—Proportioning. Correcting water-bearing strata. |
| 39 | S. D. | X | X | | | | | | | | | | | | | | | | | | | | | Base-course construction, selection of cherts, gravels, and stone for water-bound macadam. |
| 40 | Tenn. | X | X | X | X | X | X | X | X | X | | X | | | X | X | | | X | | X | | X | |
| 41 | Texas | X | X | X | X | X | X | X | X | | X | | | X | X | X | X | X | X | X | X | | X | Fill constr. Warping in concrete pavements. Base-course selection. |
| 42 | Utah | X | | | | | | | | | | | | | | | | | | | | | | |
| 43 | Vt. | X | X | | | | | | | | X | | | | | | | | | | X | | X | Field surveys only. |
| 44 | Va. | X | X | | | | | | | | | | | | | | | | | | | | | |
| 45 | Wash. | X | X | | X | | | X | | X | X | | | X | | X | X | X | X | X | X | | X | Determination of type and thickness of surface courses. Unstable soil not replaced but corrected otherwise. |
| 46 | W. Va. | X | X | X | X | X | X | X | X | | X | X | | | | X | | | X | | | | | |
| 47 | Wis. | X | X | X | X | X | X | X | X | X | | X | | X | | | X | | | | | | X | Frost heaving and general subgrade design—Peat bogs. |
| 48 | Wyo. | X | X | | | | | X | | X | | | | X | | | X | | | | | | X | Heavy clays. Fine sands. Drainage Fines in gravel to be oiled, and for stabilizing base gravel. |
| 49 | D. C. | | | X | X | X | X | X | X | | | X | | | | | X | | | | | | X | Drainage and land slides. |
| | Total | 48 | 36 | 22 | 30 | 27 | 17 | 27 | 22 | 11 | 26 | 13 | 5 | 18 | 12 | 16 | 31 | 17 | 25 | 9 | 16 | 5 | 20 | |

[1] Plan to inaugurate subgrade soil tests in near future.

[2] Report tests being made but do not specify which ones.



**SKIDDING-TEST DEVICES employed (left) at Ohio State University and (right) at Iowa State College.**

of such industrial organizations as the Portland Cement Association, the Asphalt Institute, the National Crushed Stone Association, the National Sand and Gravel Association and the National Paving Brick Association, are all vitally interested and without doubt as industrial conditions improve will expand their research activities.

The most desirable thing to be brought out among this large number of agencies is some further enlargement of cooperation, exchange of information and organized effort on specific problems. It should not be inferred from this statement that cooperation is lacking. On the contrary, the following figures show that a considerable measure of cooperative effort does exist, although it may not be generally realized. The committees of the Association of State Highway Officials, the American Society for Testing Materials and of the Highway Research Board are the principal clearing houses for highway research information. On the committees of the Association of State Highway Officials are representatives of 48 states, the Bureau of Public Roads and the District of Columbia. On the road committees of the American Society for Testing Materials are 7 representatives of federal departments, 22 of states, 17 of colleges, 8 of cities, 52 of commercial interests and 21 consulting engineers. Five federal departments, 18 state highway departments, 19 engineering colleges, 12 trade associations and 8 other national associations, as well as numerous individuals, are represented on the technical committee of the Highway Research Board.

In the past five years 121 valuable research reports have been presented and published in the *Proceedings* of the Highway Research Board, of which 21 were by representatives of federal departments, 40 by representatives of states, 43 by representatives of colleges and 17 by representatives of industries. Analyses of the publications of such institutions as the Bureau of Public Roads, Bureau of Standards, American Society for Testing Materials, Association of Asphalt Paving Technologists and the American Concrete Institute would further demonstrate that cooperation is not lacking.

The cooperative spirit is in a healthy condition, but it needs more opportunity to grow under favorable conditions for making joint efforts effective. The attendance of research workers at conferences and committee meetings is necessary for the achievement of results through cooperation. Most of the agencies engaged in highway research are local, and their work in general is upon problems of immediate importance to the jurisdictions that they serve.

Another kind of activity, the results of which are often needed to make the work of local agencies effective, is that of fact-finding investigations of national scope. Such reports as those of the Highway Research Board on the economic value of reinforcement in concrete pavements, low-cost roads, use of rail steel reinforcement bars, investigation of culverts, curing of concrete pavements and others involve the collection of data and study of conditions throughout the country and can only be done by organizations of national scope. A considerable amount of such work is needed, and provision should be made for it, especially for those cases in which there are no direct commercial interests involved.

## Developing research workers

The success of research effort in the end goes back to the individual. Without individual imagination, initiative, opportunity and perseverence we would get nowhere. Some thought therefore toward promoting conditions that make for productive effort of individual research workers as well as toward the combining of their efforts into mass attack is necessary.

The evolution of the technique of modern roadbuilding has taken place in a very short space of time. All of the previous road engineering skill built up through the centuries of horse-drawn vehicles was of little use in developing modern highway engineering to provide for the new traffic. Engineering ingenuity has had a marvelous opportunity, and the results of research have been quickly attained and quickly applied. A sound foundation for the science and art of highway engineering has been built, but the superstructure is only begun.

During this era many of the problems needing solution have been obvious, progress has been rapid, and far-reaching conclusions have been frequently reached. Now we are entering upon a different phase; the problems confronting highway engineers and highway research engineers in particular, although no less important, are complicated and intricate, and the goals are seldom in plain view. Progress may be less rapid and spectacular achievement less frequent. The time has gone by when individuals working alone without contacts with other workers and thorough knowledge of everything going on in their lines can be expected to produce important improvements in the technology of roadbuilding.

Attendance at conferences and committee meetings may be a vacation for some, but for the research engineer it is a vital necessity if he is to keep his point of view fresh and his information in good repair. The essential requisites for a research engineer are an inquiring mind, technical knowledge and ability and a large store of information pertinent to his work.

Since the matters now before us are complicated and intricate and long-sustained effort will be necessary in order to attain results, it is still necessary that we "bring about through mutual confidence, and unselfish desire to serve the public interest, a pooling of resources, of data and of new knowledge, and the organization and correlation of effort to make highway research more effective, efficient and conclusive," as stated by T. H. MacDonald in "A Proposed Program of Highway Research." (*Proceedings*, Highway Research Board, Vol. 9.)

To effect these goals, it is necessary not only that individual research workers should realize the importance of wide contacts and extensive information, but also that administrators who support the research work and who need the results of research realize the importance of these factors.

Large facilities are available for highway research, and with the return of more prosperous times they will become larger; capable and enthusiastic men are ready to go ahead, and the wisdom displayed in handling the huge expenditures to be made will depend in large measure upon the correct solution of technical problems. To solve the problems correctly, to discover new information and to prove its value, not only must intensive individual effort in the field and laboratory go forward, but it must be accompanied by cooperation and correlation of effort and the results crystallized into useful applications through free discussion in conferences and committee meetings.

In the field of highway research the active support of the work of such organizations as the technical committees of the Association of State Highway Officials, the Highway Research Board and the American Society for Testing Materials will pay large dividends. To lend encouragement and to help sustain enthusiasm in the necessarily long-continued efforts of the individual are most important functions of organized effort.

Everything that has happened thus far gives us reason to believe that future progress in the technical features of highway engineering must depend in large measure upon research. And by research is meant scientific study rather than experimentation. Much of our present-day practice is based upon the experimental method applied in the field, but from now on we must go much deeper into fundamentals. The applications of the sciences of physics and chemistry to roadbuilding problems are even now developing in important ways.

# 2... Traffic Surveys

*Miller McClintock*

ON THE POSTULATE that the only object of roads is to serve traffic, definite knowledge of traffic volume and character are requisites for sound highway planning • The kind of traffic information needed and the manner of securing it by surveys are discussed • Recording the results, interpreting their meaning and predicting the character and quality of road structure that they call for are outstanding engineering problems of the future highway designer.

FORECASTING the future highway is unthinkable without knowledge of the traffic that it will have to serve. Highways are built to carry traffic; this is the sole purpose of their existence. Traffic surveys are the means of obtaining convincing knowledge of traffic; analyzing their results and applying these to practical highway-development problems have and must increasingly become an integral part of highway engineering. The U. S. Bureau of Public Roads has exercised a very notable leadership in this movement. The engineer of the future highway should know as a familiar tool what traffic surveys are, how they are made and recorded, and then how they can be employed for reliable prediction. It is the purpose of this chapter to supply this broad information.

## Need of traffic surveys

That the suggestions made in this chapter may have specific application, it is assumed that we are dealing with a situation which confronts thousands of highway engineers throughout the country today. The typical engineer is in charge of highway construction and maintenance in an area where the highway system is largely completed; the main trunk highways have been built, and many of the secondary roads have been improved. The problem for the future is the refinement and expansion of the system through the widening of existing routes or through their reconstruction; the selection of better locations of main trunk routes; the design of bypasses and grade separations, and the improvement of the secondary road system. Good traffic surveys can aid in the solution of these problems in several fundamental ways.

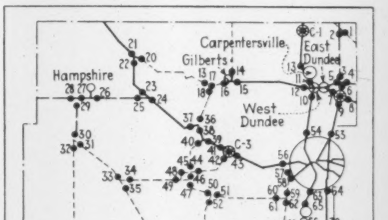


**FIG. 1—Counting-station map, indicating suitable locations and distribution of control stations and base stations.**

*Correction of Regional Plan*—The first question to be considered is: Does the general layout of the present system efficiently serve the traffic needs of the region? Unless the basic plan is adjusted to the travel requirements of the area, no amount of money put into individual routes or improvements can ever develop an economical system. There is probably no county, regional or state highway system that does not illustrate numerous faults in the basic plan—routes that have been built without due regard to actual traffic needs or as the result of political or special-interest importunities. To perpetuate such faults in the highway system is just as bad engineering as to build ill-advised new construction. Similarly there are few systems that do not show important gaps — places where new routes are urgently required. Many of these have been recognized by the highway engineer but, in the absence of specific traffic proof, he has been unable to obtain support for the needed improvement. Highway-traffic studies, properly conducted and applied, afford the information necessary for sound basic planning, not only for immediate projects but for the future construction programs.

*Design of Individual Routes*—Once a route has been selected for improvement as a necessary part of the highway system, the engineer is confronted with a problem comparable to that of the bridge engineer. He must construct a route with sufficient width and strength to carry the volume and weight of the traffic to be thrown upon it, and he must do this, especially under present economic conditions, at the least possible cost. It is apparent that he cannot solve this problem with any degree of accuracy in the absence of reasonably sound facts as to the volume and character of the traffic that is to use the route once it is improved. Here, again, the traffic survey serves as an important engineering aid.

*Protecting the Engineer* — Every highway engineer lives in a kind of perpetual hazard. Assuming that he is a person of ability and integrity, he desires to perform his functions efficiently and economically. It is his ideal to create for his jurisdiction a highway system that will give maximum benefits at minimum costs. Most highway engineers, however, are not free agents. Plans which they design are subject to approval, and construction is dependent upon appropriations by legislative agencies. These agencies often lack sound experience in highway engineering matters. Even where they are not improperly subject to political pressure, it is frequently difficult for them to weigh accurately the reasons advanced by their engineer against those of interested citizens. The result is that many conscientious highway engineers are forced every year to build routes which their own experience indicates will never justify the cost in service rendered or, at best, will render less service than other more needed improvements. It has been the almost universal experience that where adequate traffic data are available, improvements of a purely political character are forced to carry a severe handicap. Thus, even though it were assumed that an engineer know, through his general experience, exactly what should be done, it would still be wise for him to support his opinions with factual evidence.

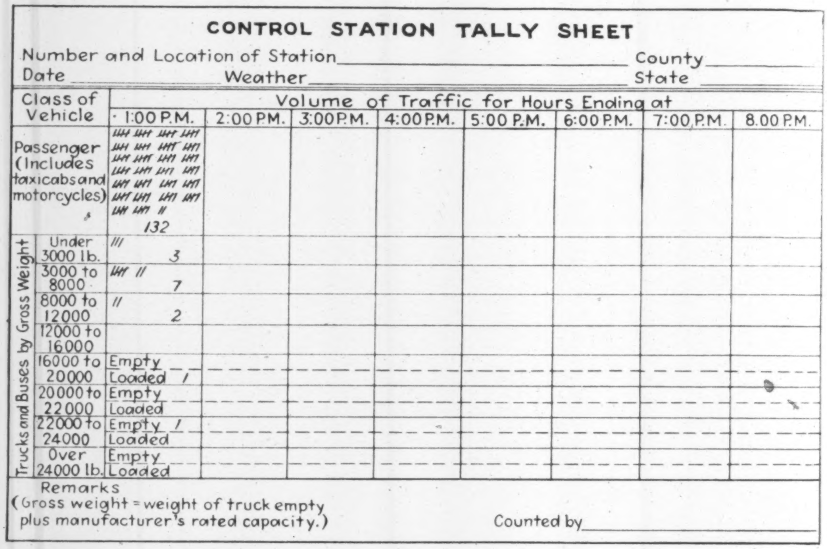
*Basic Data Required*—There is an almost infinite number of detailed questions that can be answered by specially designed traffic investigations. Attention is directed here, however, to the more simple basic problems. These may be expressed in three questions: (1) Where is the traffic and what is its volume and character? (2) Where does the traffic come from and where is it going? (3) With what facility and safety does it move?

### Making a volume count

Many different methods may be used for collecting and analyzing traffic volume data; all, however, have characteristics in common, as follows:

*Location of Counting Stations*—The number of counting stations required to cover any particular highway system will depend on how thoroughly the engineer desires to investigate the system traffic. In general, if a counting station is located at each intersection of the routes to be covered, and each intersection is laid out in such a manner that traffic is counted upon each route entering the intersection, most requirements will be fulfilled. In cases where there is a very long distance between intersections and where there is reason to believe that there is a change in traffic volume or character between intersections, additional counting stations should be used. Attention is directed to Fig. 1, which shows a typical layout of counting stations, to give a rather complete coverage of a county highway system. Each station is given a serial number for accurate identification and for ease in handling the records developed.

*Time for Counting*—Traffic is counted at different times in the year and at different times in the week for various purposes. Thus, an engineer may desire to know summer-peak traffic upon recreational routes, winter traffic for snow removal and maintenance purposes or Saturday or Sunday traffic in relation to normal week-day traffic. In most instances, however, what the engineer desires to find out is the normal average distribution in volume and



CONTROL STATION TALLY SHEET

Number and Location of Station ______________ County ______

Date ______ Weather ______________ State ______

| Class of Vehicle | | | Volume of Traffic for Hours Ending at | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | · 1:00 P.M. | 2:00 P.M. | 3:00 P.M. | 4:00 P.M. | 5:00 P.M. | 6:00 P.M. | 7:00 P.M. | 8.00 P.M. |
| Passenger (Includes taxicabs and motorcycles) | | | 𝍸 𝍸 𝍸 𝍸<br>𝍸 𝍸 𝍸 𝍸<br>𝍸 𝍸 𝍸 𝍸<br>𝍸 𝍸 𝍸 𝍸<br>𝍸 𝍸 𝍸 𝍸<br>𝍸 𝍸 𝍸 𝍸<br>𝍸 𝍸 //<br>132 | | | | | | | |
| Trucks and Buses by Gross Weight | Under 3000 lb. | | ///<br>3 | | | | | | | |
| | 3000 to 8000 | | 𝍸 //<br>7 | | | | | | | |
| | 8000 to 12000 | | //<br>2 | | | | | | | |
| | 12000 to 16000 | | | | | | | | | |
| | 16000 to 20000 | Empty | | | | | | | | |
| | | Loaded | / | | | | | | | |
| | 20000 to 22000 | Empty | | | | | | | | |
| | | Loaded | | | | | | | | |
| | 22000 to 24000 | Empty | / | | | | | | | |
| | | Loaded | | | | | | | | |
| | Over 24000 lb. | Empty | | | | | | | | |
| | | Loaded | | | | | | | | |

Remarks
(Gross weight = weight of truck empty plus manufacturer's rated capacity.)

Counted by ______________

FIG. 2—TRUCK-CLASSIFICATION FORM providing a classification of trucks by weight groups for each hour of the count.

SUMMARY RECORD OF TRAFFIC DATA

Date ______________ ______________ Highway Division

State ______________

| Number and Location of Station | Total Volume of Traffic for 24 Hours | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Passenger | Trucks and Buses by Gross Weight | | | | | | | | | | | | Total Trucks | Total all Traffic |
| | | Under 3000 lb | 3000 - 8000 | 8000 12000 | 12000 16000 | 16000-20000 | | 20000-22000 | | 22000-24000 | | Over 24000 lb. | | | |
| | | | | | | Empty | Loaded | Empty | Loaded | Empty | Loaded | Empty | Loaded | | |
| 1 (*Fig. 5b*) | 648 | 12.3 | 40.0 | 18.3 | 6.0 | 2.6 | 3.4 | 0.5 | 0.9 | 0.9 | 0.5 | 0.3 | 0.3 | 86 | 739 |

FIG. 3—TRAFFIC-DATA summary form for documenting results of traffic surveys in shape for easy reference.

character of traffic. This purpose is best answered by scheduling traffic counts in the spring or autumn months and on normal week days, Monday to Friday, inclusive. Inasmuch as normal conditions are desired, counts should not be conducted during unusual weather or under other special condition.

*Traffic to Be Counted* — For very elementary traffic-volume studies there may be no need for a classification of vehicles in the count. Simple gross flow, however, fails to reveal many of the factors that are essential for highway design. Thus, all traffic surveys now generally conducted provide for at least a segregation of passenger automobiles and commercial vehicles, and usually for some subclassification of commercial vehicles according to weight groups. This latter classification has a very fundamental bearing upon the design of the structure. While the counts are under way it is obviously desirable to obtain all the information that may be required subsequently. For this reason it is recommended that a fairly detailed classification of trucks according to weight groups be used. Such a classification is set forth in Fig. 2, which also illustrates a suitable field tally sheet for counting stations located on comparatively light-traffic routes. It will be noted that this tally sheet provides for recording traffic by each hour of the count independently; this is of considerable importance in determining the fluctuation in volume and character during the various hours of the day. Such recording by hours is imperative if the short-count traffic survey method described later is to be used.

*Duration of Counts*—An ideal traffic count would be one carried on continuously for every hour of every day; this ideal cannot be achieved because the expense would be prohibitive. Thus, even the most elaborate traffic surveys use what may be called a sampling process. Even where 24-hour counts are used they are usually conducted for only one consecutive 24-hour period, and this is taken as typical of days in the season. Occassionally, subsequent 24-hour counts are conducted in later months to determine seasonal fluctuations or trends. The use of 24-hour counts is, at best, very expensive, as a single location requires not less than three man-days.

From traffic data collected it became apparent several years ago that if the normal hourly distribution of traffic were determined at a relatively few 24-hour stations, which may be called control stations, it would be possible to conduct much shorter counts at other stations, which might be called base stations. With the typical time distribution determined at the control stations, the shorter counts at related base stations could be converted into 24-hour computed volumes. Thus, in many instances, base station counts have been conducted for only eight hours. This requires only one man-day for each of the lighter base stations. In Fig. 1 there will be found a typical distribution of 24-hour control stations and their related short-count base stations.

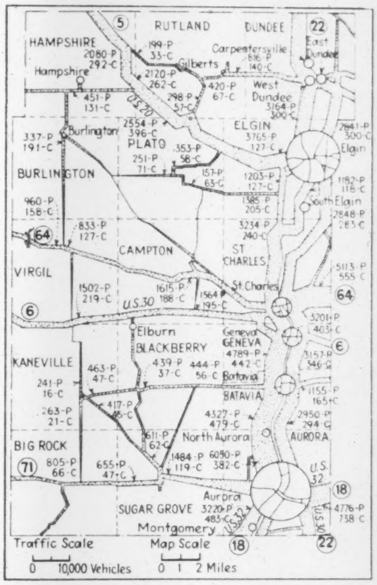

5
RUTLAND
DUNDEE
22
HAMPSHIRE
2080-P
292-C
Hampshire
199-P
33-C
Gilberts
Carpentersville
616-P
140-C
East Dundee
2120-P
262-C
451-P
131-C
U.S.20
298-P
57-C
420-P
67-C
West Dundee
3164-P
300-C
337-P
191-C
Burlington
2554-P
396-C
PLATO
ELGIN
3765-P
127-C
2841-P
300-C
Elgin
353-P
58-C
251-P
71-C
BURLINGTON
157-P
63-C
1203-P
127-C
1182-P
116-C
South Elgin
960-P
158-C
1385-P
205-C
2848-P
283-C
64
833-P
127-C
3234-P
240-C
CAMPTON
ST CHARLES
VIRGIL
5113-P
555-C
St. Charles
64
1502-P
219-C
1615-P
188-C
1564-P
195-C
U.S.30
6
3201-P
403-C
Elburn
Geneva
GENEVA
BLACKBERRY
4789-P
442-C
6
KANEVILLE
463-P
47-C
439-P
37-C
444-P
56-C
Batavia
3157-P
346-C
241-P
16-C
BATAVIA
1155-P
165-C
263-P
21-C
417-P
45-C
4327-P
479-C
2950-P
294-C
611-P
62-C
North Aurora
AURORA
BIG ROCK
71
805-P
66-C
655-P
47-C
1484-P
119-C
6050-P
382-C
U.S.32
18
Aurora
SUGAR GROVE
3220-P
483-C
4776-P
738-C
U.S.32
U.S.30
Montgomery
Traffic Scale
0 10,000 Vehicles
Map Scale
0 1 2 Miles
18
22

**FIG. 4—Traffic-flow maps serve important purpose in interpreting traffic distribution, volume and character.**

*Short-Count Method* — In 1931 the Harvard University Bureau for Street Traffic Research began extensive national investigations in 150 areas to determine to what degree counting periods could be shortened and still give reasonably accurate results. (The detailed conclusions of these investigations are printed in a monograph entitled "Short-Count Traffic Surveys and Their Application to Highway Design," copies of which can be obtained through the Portland Cement Association.) The procedure developed is too detailed to set forth fully in this paper. The essential points, however, may be summarized.

Two types of stations are used. At the long-count control stations traffic is recorded by the classifications shown in Fig. 2 for a full 24-hour period on any week day, Monday to Friday, inclusive. At short-count base stations, each of which is related to a control station, traffic is recorded by the simple classification of passenger cars and trucks for one full 60-min. period on any normal week day between the hours of 9 and 12 in the morning and between the hours of 1 and 4 in the afternoon. The two 60-min. counts at the base stations are converted into full 24-hour counts, both with respect to volume and detailed classification of trucks by weight groups, through factors derived from the long counts at a related control station.

It is by no means claimed that the short-count method gives results that are superior to those obtained by long counts, nor that in all instances there is the same degree of accuracy. The figures are, however, reasonably accurate, and the economy and flexibility of the system make it possible for many traffic engineers with limited budgets to obtain indicative data when otherwise they would not be able to obtain any data.

*Repetition of Traffic Survey*—One very important characteristic of traffic flow is that under normal conditions the volume, distribution and character of traffic do not change abruptly without reason. If this were not the case, it would, of course, be quite impossible to build any highway structure with confidence, for it might be rendered useless the day after its completion.

In every area, however, there are certain cyclic changes in traffic and certain stresses and strains that work slowly but surely, shifting the pattern of traffic demand. It is, therefore, important that an engineer, once having produced a comprehensive study of his area, should consider it as the first of a series. If possible, complete surveys should be made annually. This is entirely possible in most jurisdictions if the short-count method is used. These annual studies have a very important bearing upon the forecasting of traffic trends, a matter which will be discussed later.

## Using traffic data

No matter what method is used in collecting traffic data in the field, it is important that the results be summarized and preserved in orderly and usable form. There are many methods of documenting results. The "Summary Record of Traffic Data" form, shown in Fig. 3, will be found simple and useful and will reveal, for any counting location or a section of highway between counting locations, the volume and character of traffic as taken from the field records.

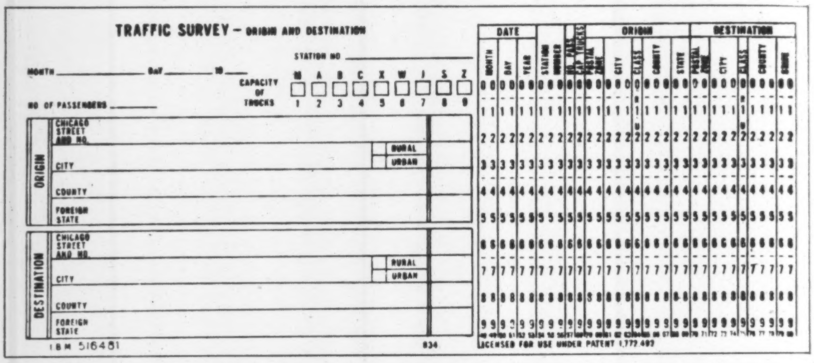
*Form of Presentation Important*—Too many of the traffic data that have been collected throughout the country have proved either useless or of relatively little value because they have never been organized and prsented in a comprehensive manner. Even engineers of experience find difficulty in interpreting figures in terms of relative volume, and such interpretation is almost impossible for the ordinary layman. It is for this reason that the traffic-flow map serves such an important purpose in interpreting the results of studies of traffic distribution, volume and character. A very simple traffic-flow map is illustrated in Fig. 4. This particular traffic-flow map shows the combined volume of passenger-car and truck traffic. Separate maps may, of course, be made for passenger cars alone, for trucks alone or for any classification of trucks.

*Application Is Vital*—The time and energy devoted to the conduct of the traffic survey will be wasted unless the engineer is able to give the results practical application in the solution of his manifold problems. Too many traffic studies result in the preparation of attractive charts and in nothing else. It is impossible to describe here all of the uses that can be made of the collected data, but some of the more important applications may be presented. Assuming that our typical engineer has prepared a traffic volume map of his area comparable to that shown in Fig. 4, what will it reveal to him?

In the first place, it will show the degree to which the existing system is adjusted to the traffic requirements of the area. Fig. 4 shows conclusively that the major traffic requirements in Kane County are concentrated on the north-and-south trunk routes near the eastern county boundary, and especially in the area between Aurora and Geneva. U. S. 20, running northeasterly across the county from Elgin, is also shown to serve a very important traffic need, while the parallel diagonal between St. Charles and Burlington is very weak. Next in importance are the east and west Routes 64, 6 and 71. The north and south routes running through Big Rock, Kaneville, Virgil and Burlington townships may be required as connecter routes, but they are revealed as relatively unimportant. The engineer has a clear picture of the varying loads thrown upon the various parts of his system. Obviously the funds at his command for improvements and expansion of the system should be placed where they will result in the greatest benefits. It would be uneconomical to spend large sums on the secondary routes if they are in reasonably good condition, while the major routes are in poor repair or overcrowded.

Care must always be exercised in interpreting a traffic-flow map. It shows what is and not always what ought to be or even what would be if there were a balanced improvement. Such a situation is potentially illustrated in the small route running westerly from West Dundee. (This illustration is purely hypothetical.) Perhaps if this route were properly improved to a connection with U. S. 20 in Hampshire township, it might be the logical route for U. S. 20 traffic. In other words, it may be that some of the traffic on existing route U. S. 20 is there because a more logical route has not been made available. Most engineers have sufficient experience in their jurisdictions to make accurate interpretation possible. There are, however, certain collateral studies which may aid and which will be discussed later.

In the second place, the data regarding traffic volume and its distribution and character make it possible for the engineer to design his improvements so that they will accurately fit the type of traffic to be carried. For example, let it be assumed that the traffic study illustrated in Fig. 4 reveals the fact that the more easterly route between Aurora and Geneva carries a very large number of heavy trucks, and that the westerly route between the same communities carries passenger cars almost exclusively. Obviously the engineer would be wasting his resources if he used the same maximum strength of structure for the latter route as would be required for the former route. The minor secondary routes throughout the country require neither the width nor the strength of pavement demanded by the major trunk routes. (See the recent studies conducted by Frank T. Sheets as consultant to the Portland Cement Association and entitled "Concrete Road Design.")



TRAFFIC SURVEY – ORIGIN AND DESTINATION

STATION NO ____

MONTH ____ DAY ____ 19__

NO OF PASSENGERS ____

CAPACITY OF TRUCKS

M A B C X W J S Z

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1 2 3 4 5 6 7 8 9

ORIGIN

CHICAGO STREET AND NO.

CITY ☐ RURAL ☐ URBAN

COUNTY

FOREIGN STATE

DESTINATION

CHICAGO STREET AND NO.

CITY ☐ RURAL ☐ URBAN

COUNTY

FOREIGN STATE

IBM 516481

834

DATE: MONTH, DAY, YEAR

STATION NUMBER

NO. PASS.

CAP. TRUCKS

ORIGIN: POSTAL ZONE, CITY, CLASS, COUNTY, STATE

DESTINATION: POSTAL ZONE, CITY, CLASS, COUNTY, CODE

LICENSED FOR USE UNDER PATENT 1,777,492

FIG. 5—Form for interview method of conducting an origin and destination survey of traffic.

## Origin and destination counts

As has been noted, care must be taken in the interpretation of traffic-flow data. One very important collateral study to assist in this interpretation is an origin and destination survey. It answers the question, "Where does the traffic come from and where is it going?"

The proper layout of this survey is similar to that described for the volume study. Usually, however, fewer stations will be required. They should be located in such a manner as to cover all of the significant movements of traffic throughout the entire system. They are designed to translate the volume studies from what is into what ought to be.

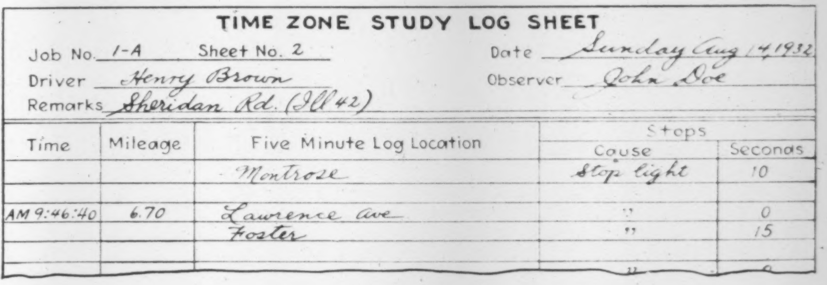
There are two general methods for conducting origin and destination studies. One may be called the card-reply system, and the other may be called the interview method. By the former, drivers are handed a stamped postcard on which they are requested to fill in certain answers regarding the character of the vehicle, the points of origin and destination and the route followed. The card is mailed to engineering headquarters, and the analysis of results is conducted.

By the interview method, drivers are actually asked the necessary questions at each station, and the answers are checked by the observer on a suitable form. Both methods are satisfactory. The former is particularly adaptable to heavy-traffic routes where the stopping of traffic for even a brief interview might cause unreasonable inconvenience. For light-traffic routes, it is believed that the interview method is definitely superior. Fig. 5 illustrates an interview form which combines a space at the left for recording information by the field checker and at the right a space for coding and punching the data where machine tabulation is to be used. (This card was used in a joint study of the Chicago Metropolitan area by the Illinois highway division and the traffic and public safety committee of the Chicago City Council, John A. Massen, chairman.) This method of analysis is economical where many thousands of cards must be analyzed. The same type of information recorded on a simple 3x5-in. card would serve the purpose adequately in most smaller jusisdictions.

As in the case of volume studies, it is important in origin and destination studies to classify commercial vehicles according to weight groups. The normal flow of commercial traffic is often very badly distorted by the inability of trucks to use certain direct routes because of legal restrictions, the existence of weak bridge structures or impaired clearances. It is recommended that the same classification be used as is illustrated in Fig. 2.

In brief, the origin and destination study reveals why traffic is at a certain point on a given route. This may be illustrated by a return to Fig. 4 and the hypothetical problem regarding the improvement of the route between West Dundee and U. S. 20 in Hampshire township. Let it be assumed that the origin and destination study shows that the greater part of the traffic on Route 22 just south of West Dundee has an origin or destination somewhere in or west of Hampshire township. This would certainly lend very strong factual support for the improvement of the route directly west from West Dundee, as the present condition of that route is such as to result in an uneconomical routing by way of Elgin.

Origin and destination studies are invaluable in the analysis of bypass problems. The probable utility of a bypass route can be forecast accurately before it is constructed.



TIME ZONE STUDY LOG SHEET

Job No. 1-A Sheet No. 2
Date Sunday Aug 14,1932
Driver Henry Brown
Observer John Doe
Remarks Sheridan Rd. (Ill 42)

| Time | Mileage | Five Minute Log Location | Stops | |
|---|---|---|---|---|
| | | | Cause | Seconds |
| | | Montrose | Stop light | 10 |
| | | | | |
| AM 9:46:40 | 6.70 | Lawrence ave | " | 0 |
| | | Foster | " | 15 |
| | | | | |
| | | | " | 0 |

FIG. 6—LOG SHEET for recording speed of traffic by automobile drifting at the average speed of the traffic stream.

## Collateral studies

The volume study described herein is a basic tool for the highway engineer, and the origin and destination study is its most important adjunct. There are a very large number of collateral studies that may be necessary and useful in dealing with special conditions. Two of these may be mentioned.

*Facility Studies*—This study is designed to reveal those portions of the existing highway system where the speed of movement is unduly retarded and to show the causes for the congestion. It is required in any system where congestion and delays are sufficiently frequent to require remedy. This study is commonly referred to as a speed-and-obstruction study or a time-zone study. There are various ways of conducting it, but the simplest and most effective for the average engineer is to make and record observations from a car drifting in traffic; that is, the observer's car is driven at a speed which approximates that of the average vehicle in the stream.

Fig. 6 illustrates one type of log sheet upon which to record field data. The first entry is the time of the start of the run, zero mileage as shown in the tripodometer, and the location of the start of the run. The next and subsequent entries are made at 5-min. intervals showing the time, the mileage, and if possible an identifying location such as an intersection. Any stops made during each 5-min. interval are recorded in the "Stops" column with an entry of cause, and duration in seconds as determined by the observer from his stopwatch. Instead of logging the route by 5-min. time intervals, shorter or longer intervals may be used, or fixed log locations may be established prior to the field work. An analysis of the field sheets shows the normal overall speed for any section of the route studied, and the cause and duration of delays.

*Safety Studies*—There is very properly a growing public demand that highway systems not only be adequate in plan, width and strength to carry traffic efficiently, but that, so far as possible, they be constructed so as to provide maximum physical safety. Many routes that are satisfactory in every other way ought to be abandoned and relocated for the sole reason that they are unduly hazardous. Such routes are often those which have a large number of grade-crossings with a railway. On the other hand, it may be said that many very expensive grade-separations have been constructed throughout the country where an accident analysis would by no means have justified the expenditure, or where it would indicate other locations in far greater need of protection.

There are definitely standardized methods of conducting accident surveys and of maintaining accident records. The leader in this field of work is the National Safety Council, with head offices in Chicago and with many local councils throughout the country. From this organization the engineer may obtain help and guidance.

## How far is forecasting practicable?

No one can approach the problem of forecasting probable future volume and character of traffic with any degree of confidence. At any rate, this cannot be done with available technique, though better methods may be developed in the future.

At present, the Harvard University Bureau of Street Traffic, through its Research Fellow, Russel Burnet, is conducting studies of methods for projecting probable traffic volumes and weights for individual routes, through grants made from the Rockefeller Foundation by the Harvard University Committee on Research in the Social Sciences.

During the last decade, certain trends made themselves apparent. These could be used with some security to project probable traffic increases from year to year and, it was thought, for future decades. The depression so completely modified these trends as to invalidate most of the projections. It is certain, however, that the engineer will be able to come much closer to approximating the probable use of a route through its useful life by reference to certain basic factors than he can on the basis of pure guesswork.

The best possible basis for forecasting is actual traffic-flow data, collected over a long series of years, which establish in a given jurisdiction certain norms or trends in traffic development. It is for this reason that annual studies of volume were urged earlier in this discussion. Unfortunately, such data are rarely available today. Related factors must, therefore, be used.

Traffic is a function of population mobility in terms of currently used types of vehicles. Thus, the normal traffic to be expected in the future upon any route is dependent primarily upon the size of the population served modified by motor-vehicle registration. Somewhere between the future trend-of-population curve and the future trend-of-registration curve lies the probable-use curve. With this as a basis, the engineer must apply additional factors which affect the particular locality and the particular route.

## Conclusion

The past few years have shown a far greater activity in traffic-survey work than has ever been witnessed in any similar period. Through local, state and federal agencies, unprecedented sums have been made available for traffic studies as a means of ready employment for the needy. Engineers should take advantage of this opportunity to obtain much-needed information.

But here a word of warning is also timely. Many of the studies that have been conducted have been ill-advised, hurried in design and carried on in such a manner as to throw doubts upon the accuracy of the results. In other instances the studies, though well done, have been filed away without any attempt to give the results practical application.

In the long run the utility of traffic-survey work, as an adjunct to highway planning, design and construction must depend upon the interest and understanding of the highway engineering profession.

# 3 . . . Highway Rerouting

## C. H. Purcell

INCREASING TRAFFIC SPEEDS, weights and intensities call for shorter and straighter roads • How to meet this demand—whether by rerouting or by rectifying existing routes—is a question of transportation economics • The design and construction problems are completely within our grasp, but the economic problems involved call for facts and the training to evaluate them, which have in large measure yet to be developed by those in the highway field.

REROUTING as a problem of the future highway calls for a knowledge of transportation economics rather than of locating and design practices. It is consideration of the economic problems that is undertaken in this chapter. About many of these, present factual knowledge is so scant that argument and reasoning must be rather general, but some fundamental considerations can properly be presented.

### Reviewing the situation

The urgent necessity for general modernization on a radical scale becomes apparent at once when it is considered that in the United States in a period of barely 30 years there has been an almost 100 per cent substitution of the gasoline or fuel-oil motor for the domestic horse as the motive power for vehicles traveling on highways. In that time the horse has practically disappeared from roads and streets, and more than 20,000,000 motor cars have taken his place. Average rural vehicle speeds have changed from 5 to 40 miles per hour, and average rural trips have increased from 5 to more than 100 miles. The total number of vehicle-miles run on our highways probably has increased more than 10,000 per cent. These unprecedented changes in transportation had rendered a good proportion of our existing roads hopelessly obsolete by about 1920.

Practically all highway modernization projects are undertaken to accomplish one or more of three essential purposes: improvement of operating safety, increase of operating convenience and reduction of operating cost for the traffic using the road. These three general purposes include increase of average speed and road capacity, relief of congestion and dozens of other factors relating directly to safety, convenience and cost.

The three essential purposes of modernization mentioned involve naturally an improvement in the standard of the highway, which can be attained only by adapting or adding to the existing road, or by building a new road entirely or a new portion thereof—in other words, by relocation. Every highway-modernization project involves potentially a comparison between an adaptation and a relocation. The decision as to procedure must be made on the basis of the comparative efficiency of total service that can be rendered by the two alternatives.

During the past few years many attempts have been made to solve this problem in individual cases, and the result has been a great number of highway relocations of varying degrees of real value. It is evident that a proper solution in any case must be founded on a thorough consideration of not only the initial and future cost of the improvement and its effect on the vehicles using it, but also of the salvage values in the existing road; the rights of the owners of abutting property; the characteristics of the traffic; future adequate service based on increasing, stabilized or even decreasing population; the varied facts involved in the actual financing of the project, and the many other factors having an intimate bearing on the case.

It follows that the man who solves such a problem must be more than an engineer in the ordinary sense—he must be a thoroughly capable, intensively trained and highly specialized analyst of highway economics in the broadest sense. It seems that engineers with such qualifications are rather rare, the result being that the general economic policies which have governed the development of modern highway relocation thus far are in a not entirely satisfactory status. Prejudices, assumptions and individual opinions rather than known facts are often the basis on which development is undertaken. For instance, a relocation may reduce a maximum gradient from 6 to 4 per cent, but how many, if any, highway engineers can state with authority supported by physical proof, the economic value of a 4 per cent gradient as compared with 6 per cent?

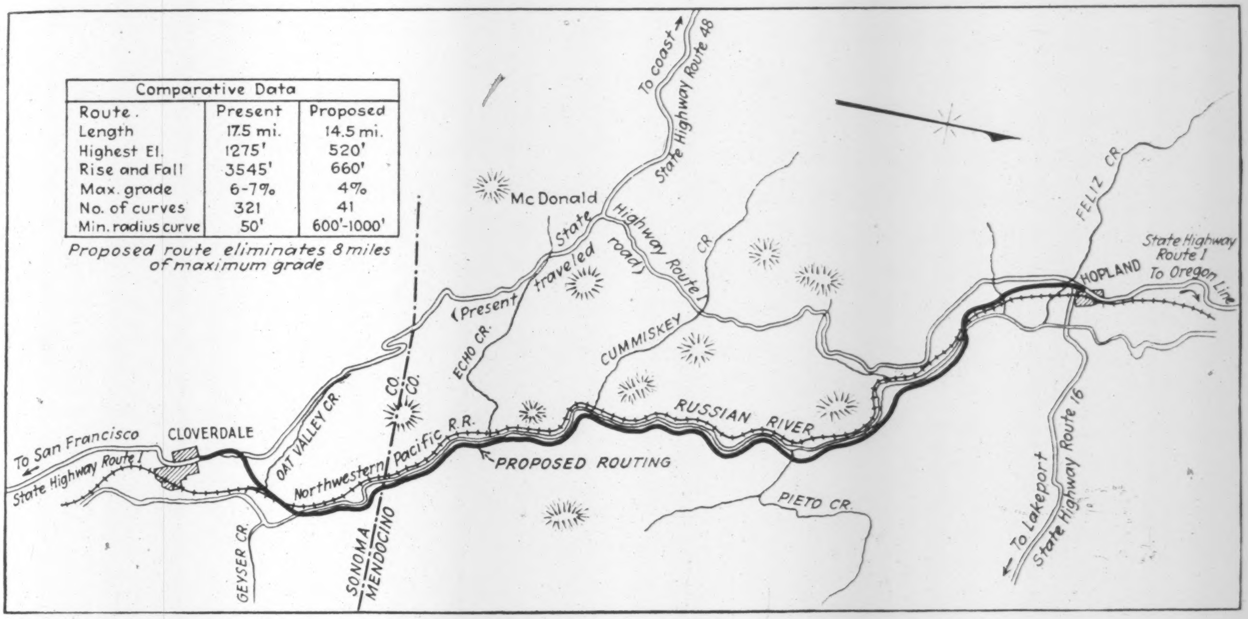
### Some rash economists

One of the natural effects of the procedure of the economic cycle in which we now find ourselves, successively from unequalled prosperity to the depths of a serious depression, has been to direct public attention as a whole rather forcibly to economics. It takes no great analytical ability to perceive a close relationship between the modern highway development and the economic life of the public. It was therefore entirely natural for many pseudo-experts to interest themselves in economics and furnish expert advice in the economic solution of highway development.

Economics is an exceedingly complex science. It involves a surprising aggregation of tangible and intangible factors, all of a variable nature, and so closely interrelated that all are delicately susceptible to variations in any of the others. This remarkable combination of the tangible and the intangible had led many persons to draw an apparently obvious conclusion without analytically considering the other less apparent factors that might seriously influence the conclusion. It is neither reasonable nor possible for the average engineer, or the average in any other line of endeavor, to acquire a practical working knowledge of economics without years of specialized study. Not many of the highway engineers now practicing throughout the country have thoroughly specialized in that particular study; consequently not many are qualified to formulate working policies for a procedure such as the relocation of a highway, which is so intimately bound up with economic principles.

It is suggested that our knowledge of highway-location economics is still somewhat meager and does not always permit the formulation of definite policies of procedure relating to relocation. Our immediate efforts for standardization of such procedure should be directed intensively toward increasing the information leading to the establishment of definite economic facts on which such procedure can be intelligently based.

These desired facts must include and comprise definite data on the real effect of distance, curvature and gradient on automobile operation; the actual effect of different types of surfacing on operation; actual traffic speeds; the real effect of traffic delays; the true cost and relative efficiencies of different methods of financing; the actual cost of roadway maintenance, and many other related subjects. Thanks to the efforts of a few engineer-investigators, we now possess some information on some of these subjects, but it seems that when the assumptions, guesses, opinions, etc., are subtracted from the total of our assumed "knowledge," the residue of actual, reliable facts is truly not large. Most of the desired information can be secured only by the patient, laborious effort of continued research and experiment—not by the easy shortcut of assumption.



| Comparative Data | | |
|---|---|---|
| Route. | Present | Proposed |
| Length | 17.5 mi. | 14.5 mi. |
| Highest El. | 1275' | 520' |
| Rise and Fall | 3545' | 660' |
| Max. grade | 6-7% | 4% |
| No. of curves | 321 | 41 |
| Min. radius curve | 50' | 600'-1000' |

Proposed route eliminates 8 miles of maximum grade

**EIGHT MILES of maximum grade were eliminated by this relocation along the Russian River in Sonoma and Mendocino counties, Calif.**

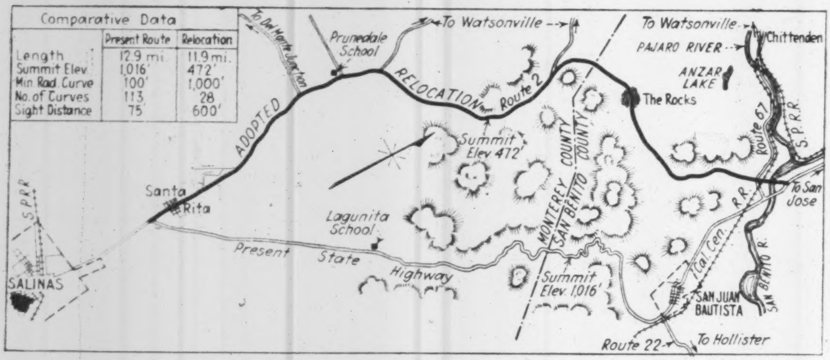
A strong tendency exists to promote and justify reroutings largely on the basis of the assumed savings in automobile operations that will result from reduced curvature, gradient, driving time, distance, etc. These are the apparently obvious advantages of relocation, but the interesting point in this connection is the great importance and the enormous evaluation that is attached to these advantages in the face of the fact that in most cases engineers do not agree as to these values and have not yet devised a satisfactory means of actually measuring them in dollars and cents. We indulge in pure rationalization, which is scientifically inexcusable; yet even a casual perusal of the current engineering literature and reports will attest to its general practice in the highway field. Inasmuch as in the usual case a rerouting involves more construction cost than an adaptation of the existing road, it is readily seen that there exists a dangerous tendency to attempt to justify actual expenditures on the basis of theoretical and assumed benefits. It is equally evident that a high degree of conservatism is necessary to the intelligent consideration of such expenditures, if premature or wasteful spending of public funds is to be avoided.

If the foregoing comments be accepted as correct, it might seem that the financial justification of highway rerouting is, at present, practically impossible or, at least, decidedly doubtful. It is not the intention to create this impression, but rather to stress the difficulty of the problem, to emphasize the dangers of entrusting its solution to those inexperienced in the particular field of location economics, and to urge that such responsibilities be given only to those engineers who by concentrated effort in their special field have developed a knowledge of economic facts which can stand up under scrutiny, analysis and criticism from all angles. When highway authorities as a whole recognize the importance of the work of highway location, the first step will have been taken toward the formulation of a safe and efficient procedure in the matter of highway reroutings.

## We must modernize

In the meantime the demand for highway modernization is so great that development along these lines must proceed in spite of the lack of knowledge of the governing principles. Efficient procedure might include, therefore, first the undertaking of those projects that involve the least complicated problems. A case in which a relocation can be made with complete assurance that it is the correct procedure is one in which adaptation of an existing road is practically impossible owing to physical limitations. An example might be a 40-ft. city street with a solid fronting of expensive buildings and improvements where an 80-ft. roadway is desired. The prohibitive cost of widening would naturally indicate a rerouting, and the problem would then be to find the most efficient new route. There are many such cases in existence, and relocation as a program may well be directed in priority thereto.

There are many cases where modernization by relocation will involve less construction cost than adaptation of the existing road and yet will provide, at least equal, and generally improved, standards of design. As a rule, in such cases, the relocation can be undertaken with reasonable assurance that it is the proper procedure. Examples such as this are among the more obvious, but even in such apparently obvious instances the true value of the relocation


To Del Monte Junction
Prunedale School
To Watsonville
To Watsonville
PAJARO RIVER
Chittenden
ANZAR LAKE
The Rocks
ADOPTED
RELOCATION
Route 2
Summit Elev. 472'
MONTEREY COUNTY
SAN BENITO COUNTY
Route 67
S.P.R.R.
To San Jose
Santa Rita
S.P.R.R.
Lagunita School
Present State Highway
Summit Elev. 1,016'
Cal. Cen. R.R.
SAN BENITO R.
SAN JUAN BAUTISTA
SALINAS
Route 22
To Hollister

| Comparative Data | Present Route | Relocation |
|---|---|---|
| Length | 12.9 mi. | 11.9 mi. |
| Summit Elev. | 1,016' | 472' |
| Min. Rad. Curve | 100' | 1,000' |
| No. of Curves | 113 | 28 |
| Sight Distance | 75' | 600' |

**COMPARISON** of line and grade of old and new routes on a relocation of San Juan grade in Monterey and San Benito counties, Calif.

must have taken into consideration such factors as destination of traffic and total road mileage in the area. It is entirely possible that a relocation that provides better design standards for less construction cost may actually be a less efficient project economically than an adaptation, owing to increased total mileage of public road to be permanently maintained. The very fact that this condition seems paradoxical serves to emphasize the need for the most searching analysis on the part of the engineer.

### Multiple routes or widening

In connection with rerouting to avoid congestion, some consideration has been given to the proposition of providing separate roads for passenger and freight traffic in the more highly developed areas.

The constantly increasing use by commercial trucks of public highways during the last few years has raised the question as to the right of these carriers to use the public roads for profit. The accepted necessity for local distribution of freight and for urban delivery service, the necessity for thicker pavements and wider roads to carry trucks, the preponderance of passenger-car traffic, the method of financing highways, the development of diesel trucks using tax-free fuel oil, the question of truck competition with the railroads, the growth of the automobile and truck-building industries, the lack of uniformity of laws regulating truck commerce and many other factors combine to make the use of public highways by the truck a vexing problem. Passenger cars outnumber trucks about ten to one.

Until the matter of the regulation of trucking activities is more definitely and uniformly determined, it would seem wise to defer a more general attempt to build separate highways for passenger cars and trucks.

It would seem also that for the present, provision for the different classes of traffic could be made in the width of roadway and in the utilization of the right-of-way rather than by multiple routes. The development of multiple routes has been attempted in a sense in some cities, by defining by ordinance certain existing streets as truck routes, but different conditions justify and probably make such procedure desirable.

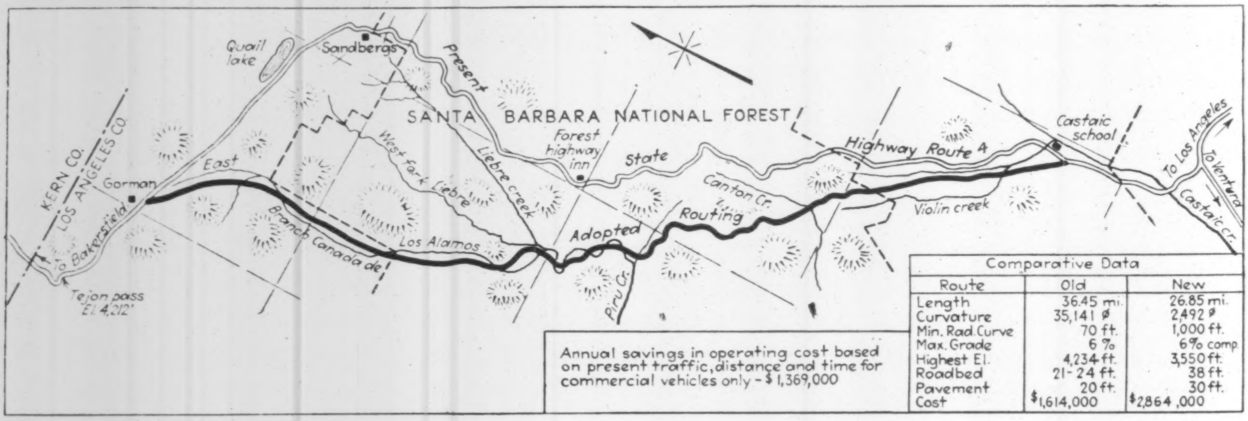
The matter of utilization of the right-of-way has been a subject of much study by planning commissions during recent years, and a number of ingenious ro way sections have been worked out i volving multiple-lane roads, paral service roads, parking areas, etc., i the segregation of various classes traffic. It is interesting to note th practically all of these various plans volve and include additional paveme dimensions and right-of-way width, a additional cost to segregate and provi for the truck traffic. The problem segregation is evidently as much one psychology as of highway engineerin and it must be handled accordingly, least for the present.

### Relocation to ultimate needs

One principle of relocation often ha received insufficient study in the pas It is the provision for still furthe revenue growth and modernizatio Examples are in evidence where a original existing road has been modernized twice by successive relocation within the past twenty years and now faces a third revision. The cause ha been an attempt to meet immediat demands and failure to provide fo basic design permitting further growth In such cases the engineer may justly be accused of either timidity or lack o vision.

It is not always practicable o economically efficient to design a relocation to an ultimate standard, but it is usually possible so to design it that it can be adapted to the ultimate largely by additions or stage development rather than by change or further rerouting. Such a design requires invariably the greatest foresight, a broad conception of the problem and the influencing factors, and the ability to visualize. Alignment and grade must usually be considered simultaneously. The speed capacity of the modern car dictates high standard of alignment. Trucks operate at higher speeds. Physical conditions and economy often place a limit on the standard of alignment. Properly superelevated curves of 1,000-ft. radius can be comfortably negotiated by an automobile at speeds up to 55 and 60 miles per hour.

**RELOCATION** of Ridge Route in Los Angeles County with comparison of line and grade of old and new route.


Quail lake
Sandbergs
Present
SANTA BARBARA NATIONAL FOREST
Forest highway inn
State
Highway Route 4
Castaic school
To Los Angeles
To Ventura
Castaic Cr.
KERN CO.
LOS ANGELES CO.
Gorman
East
West fork Liebre
Liebre creek
Canton Cr.
Violin creek
To Bakersfield
Branch Canada de Los Alamos
Adopted
Routing
Piru Cr.
Tejon pass El. 4,212'

Annual savings in operating cost based on present traffic, distance and time for commercial vehicles only - $1,369,000

| Comparative Data | | |
|---|---|---|
| Route | Old | New |
| Length | 36.45 mi. | 26.85 mi. |
| Curvature | 35,141° | 2,492° |
| Min. Rad. Curve | 70 ft. | 1,000 ft. |
| Max. Grade | 6 % | 6% comp. |
| Highest El. | 4,234 ft. | 3,550 ft. |
| Roadbed | 21-24 ft. | 38 ft. |
| Pavement | 20 ft. | 30 ft. |
| Cost | $1,614,000 | $2,864,000 |

Expenditures to achieve such a minimum standard are justified on some roads, even though expensive. We are continually faced with the question of allowable maximum grade. A slightly higher maximum rate of grade, with straight or easy alignment, is preferable to a lower rate of grade with lower standard of alignment. Adequate sight distance must be provided, not only for horizontal but also for vertical curvature. At least 800 ft. of clear sight distance should be provided on two-lane roads. We have already experienced development of highways into multiple lanes for traffic. On a relocation designed for at least four lanes of traffic, a minimum sight distance of 800 ft. is not so necessary. Rolling grades may be employed in the original construction, since these may be revised later; but economy would dictate that these should be surfaced with salvageable or temporary pavement until the ultimate development is undertaken.

Ample right-of-way to accommodate ultimate development is necessary. It should be sufficient to include the entire width occupied by the constructed highway or the future widening. This may be accomplished in many cases by providing slope rights for embankment and excavation to the limits of ultimate development. Setback lines and zoning can be employed in protecting the highway for future expansion against abutting development.

## Summing up

The problem of rerouting or relocation must be approached first with the broad concept and fundamental principles governing highway location. Adaptation of the existing road or relocation can conceivably be determined upon on this basis alone. We may then proceed with consideration of the further factors, such as reduced distance, avoidance of congestion, destination of traffic, duplication of road mileage, future maintenance and other modifying influences. Conservative evaluation of these factors, however, is indicated until more extensive research develops dependable data.

Finally it may be said that it really is not possible to formulate any general rules or code of procedure for the development of a system of reroutings for the purpose of highway modernization. Every such project is distinctly an individual problem in itself. In many cases relocation simply constitutes avoiding the issue and taking the easy way out. In other cases a decision to adapt the existing road could be, and often is, the result of lack of courage to execute a bold piece of engineering. In every case the proper engineering solution can be reached only by a thorough economic analysis. An attempt to standardize the procedure of this analysis would probably reduce the quality of the result.

# 4... Rational Road Design

## *F. T. Sheets*

IN THE PAST DECADE great advances have been made toward the rational design of pavements • Test roads, scientific research, field investigations and mathematical analyses all have combined to remove the necessity for guesswork in highway design • In the following discussion the results of a wide survey of research data and practical experience are resolved into applicable formulas for the design of pavements for future main traffic roads.

A RATIONAL highway plan, based on practical statewide traffic and economic surveys, is an essential prerequisite to the orderly development of a highway system. Among other factors, it will give proper weight to:

1. The relative traffic importance of the different classes of roads and streets.
2. The amounts of motor-vehicle revenues paid by residents of metropolitan, urban and rural areas.
3. The amount of travel by each group on the several classes of roads and streets.
4. The distribution of available funds so as to meet traffic demands and simultaneously preserve equity for each group of residents.
5. The actual highway needs and the revenues required to meet them.

By its obvious soundness and fairness, a rational plan attracts popular support and promotes continuity of an adequately financed highway program.

The design for every highway project should harmonize with this predetermined broad state highway plan. Only in this way can funds be expended wisely and with proper appreciation of future needs. The same traffic and economic surveys that form the background for the general state-wide plan will yield the data needed for forecasting the traffic demands for a specific project. Occasionally supplementary studies will be needed to produce more detailed information.

The making of liberal forecasts of future traffic speeds and intensities for a given project is not a schoolboy problem. Yet there is nothing mysterious about it. Data on traffic trends, population trends, potential development of adjacent industries, the geographical significance of the project and its relation to other highways will guide both imagination and reason. We temper the result with common horse sense and spice it with an appreciation of the potentialities of automotive advance, and we are ready to design.

This may sound fanciful. It is not so meant. We can make very close predictions of traffic volumes and frequency of the various vehicle weights. These give us ample data on which to base widths of right-of-way, roadway cross-sections, traffic lanes, paved surface, shoulders and structures, as well as the structural design of the pavement to provide adequate load-carrying capacity; but we must raise our sights appreciably on such matters as alignment, gradient, superelevation, and the elimination of highway and railway grade-crossings if we expect to keep up with the speed trends and safety demands of future highway transport.

No attempt will be made here to describe methods of making traffic surveys. Recent advances in this field have simplified procedure to the degree of practicability demanded by practicing engineers. Traffic surveys have long since passed the stage of mere academic interest; they are a practical tool for the highway planner and designer.

However, emphasis must be placed on the fact that such surveys should show not only the total volume of traffic but also should segregate the vehicles, heavier than the ordinary passenger car, into general weight groups. Proper allowance may be made for future traffic increase, thus making available to the designer (*a*) the total expected volume of traffic on which to base general features of design; and (*b*) the expected number of each size of wheel load as a basis for designing the paved surface to have adequate load-carrying capacity.

Traffic surveys of an unimproved road are practically useless, because after improvement the road attracts traffic to it. However, surveys of an improved road of the same geographical and industrial significance as the unimproved highway under consideration will be a sufficient guide to design.

## General design features

The following discussion of general design features relates particularly to primary roads on which the potential increases in traffic demand are greatest; but the same features merit serious study on secondary roads of less traffic significance.

*Location*—Location to meet future demands is of the greatest importance. Circuitous routes exact a heavy toll on the motoring public and yield practically nothing in return. Local service considerations should have little place in planning primary roads. Yet the pressure on highway executives to debauch primary road locations to serve local farmhouses and to run down the main streets of small communities is terrific, and it frequently takes a high order of moral courage to do the right thing.

Too frequently the local people and their legislative representatives cannot see the broader vision; too frequently the highway engineer fights the battle for the public's interest single-handed; motorists' organizations, highway-users groups, and chambers of commerce or similar organizations of larger communities should rally to the support of the hard-pressed highway executive.

A specific illustration comes to mind. The state of Illinois was planning a trunk line from Springfield to Joliet, a part of the Chicago to St. Louis highway. The projected location saved 30 miles in distance and eliminated 31 grade-crossings as compared to the location meeting with popular favor. New right-of-way was required for practically the entire length. Pressure was terrific, but the state highway department stood by its guns and built directness and safety into the final improvement. The results have been that everyone now agrees that the location was right, lives have been preserved, and the traveling public is saving approximately $1,000,000 a year in reduced driving cost, due to elimination of the excess distance. Thousands of such examples are available throughout the country.

Too much emphasis cannot be placed on proper location, and the most daring conceptions of location today will be fully justified by the traffic conditions of tomorrow.

*Alignment and Grade*—These are, in reality, details of general location. The detail and general problems must each be properly solved if adequate provision for the future is to be insured. They are not independent.

Assuming that a proper general location has been selected, future needs require daring treatment of alignment and gradient problems. Motor vehicles are being driven at greater and greater speeds. Future trends will be definitely in this direction. Therefore, the factors of sight distance, horizontal curvature, superelevation, gradients and vertical curvature must be given greater emphasis; and to avoid premature obsolescence in the improvement, speeds of 100 miles per hour should be provided for on main roads. This may sound radical, but a glance backward to the speeds of travel and related design policies of only fifteen years ago reveals how far we have come and how inadequate for present traffic conditions are the roads designed then.

*Right-of-Way* — Rights-of-way for primary roads should, wherever possible, be sufficiently wide to permit widening of the paved surface and related structures to accommodate future traffic increases. Near metropolitan centers, right-of-way width should be about 200 ft. when obtainable at any reasonable cost. In rural sections 100 ft. is the minimum width desirable.

*Shoulders*—Shoulders should be not less than 10 ft. wide. This induces safety and permits stalled cars to be parked clear of the paved way.

*Traffic-Lane Width* — The desirable width of traffic lanes is 10 ft. This is generally accepted practice and promises to meet adequately future demands for both rural and city pavements. Where very large numbers of maximum sized vehicles are expected, even greater lane width may be desirable.

*Ditches*—Except where drainage conditions prohibit, side ditches should be as shallow as possible and should be constructed with very flat slopes between the shoulder and the bottom of the ditch. This is a real safety feature and improves appearance as well.

*Alternate Designs*—Once the expected weight and frequency of wheel loads has been determined for a specific highway project, the engineer may logically develop adequate alternate designs, using various available paving materials. Since all designs are for use under the same conditions, logical reasoning dictates that they should have equal stability or load-carrying capacity for the traffic to be served. With this condition satisfied, studies may then be made of the relative first cost, maintenance cost, annual road cost, vehicle-operation cost and the total annual cost of transportation for the designs considered. The most economical design for the specific location will then become evident.

## Pavements

Let us study for a moment how a pavement functions. Practically all pavements are laid on a prepared subgrade of natural soil. The subgrade soil has a definite limit of pressure per square inch, which it can carry without being depressed or displaced. This varies with seasonal moisture and other conditions, and its supporting power during a seasonal period of unfavorable conditions is the governing factor. A vehicle wheel puts an intense pressure upon a relatively small area of the pavement surface. Therefore the pavement, by means of its base or component materials, must be capable of reducing the intensity of this pressure or distributing the load so that the allowable pressure on the subgrade is not exceeded. If this condition is not satisfied, the pavement fails.

The following general types of pavements are in common use:

1. *Rigid Types*:
   - (*a*) Concrete. In this type the concrete slab has beam or slab strength and provides simultaneously and in one unit the wearing surface and the supporting base.
   - (*b*) Concrete bases, supporting, by beam or slab strength, surfaces of asphalt, tar, bituminous filled brick, wood block, etc.
2. *Flexible Types*:
   - (*a*) Bases of gravel, crushed stone, or of these materials mixed with asphalt or tar and having practically no beam strength, supporting various surfaces.

Let us compare the action of the so-called rigid types, such as concrete pavements or concrete bases supporting other surfaces, and that of the so-called flexible types.

*Rigid Types*—A concrete pavement or base has beam or slab strength. Therefore, when a wheel load is applied, the flexural strength distributes the wheel load over a relatively large area of the subgrade and reduces the subgrade pressure to allowable limits. It is obvious, also, that a base having beam strength will bridge over weak spots or irregularities in the subgrade, and that, except on soils of very high supporting power, such pavements may be much thinner for the same load than other pavements that do not have beam or flexural strength. Extensive tests have shown that surfaces of brick, asphalt, etc., when placed on a concrete base, add little if any strength. They may cushion the base somewhat, but under modern rubber-tired vehicles the benefit in strength is negligible.

*Flexible Types*—Flexible bases, supporting various surfaces, act in an entirely different manner. They have practically no flexural, beam or slab strength and rely on the mechanical interlock of the base material to diffuse the intensity of pressure created by the wheel load on the pavement surface, so that the resulting pressure on the subgrade is within allowable limits. Naturally this condition requires on average soils much greater base thickness than in the case of the rigid types having flexural strength, and as the loads increase a correspondingly greater thickness of flexible base is required.

The flexible type of construction is dependent to a marked degree upon subgrade uniformity. Local subgrade weakness cannot be bridged by a flexible base, and consequently local subgrade failures are quickly evidenced in pavement-surface irregularity. This sets up greatly increased impact stresses under traffic and hastens destruction. Flexible pavements must also have sufficient thickness to remain stable under seasonal periods of subgrade weakness.

## Subgrade variation

Subgrade supporting power varies between rather wide limits. The soft plastic clay soils will have supporting power as low as 5 lb. per sq.in., while the very stable gravel subgrades may develop a supporting power of approximately 50 lb. per sq.in. A wealth of data on this subject is contained in the bibliography. There will be exceptional subgrades which will go beyond these ranges, but the general practice in design has been to allow subgrade pressures ranging from 10 to 30 lb. per sq.in.

Preliminary to making designs for a highway, it would be highly desirable to make field bearing-power tests to determine allowable pressure limits. Such tests should be made with a loaded area approximately 3 ft. in diameter, because investigations have clearly demonstrated that reliable and consistent results cannot be obtained with the smaller loaded areas. Such tests should of course be made during the period of the year when the soil is in its weakest state, so as to develop average pressure values for design purposes. These tests are relatively simple and are not subject to the complexities of laboratory analyses of soil properties.

Much has been done to classify subgrade soils. The Bureau of Public Roads has developed soil technique to an advanced stage and has devised standard tests to evaluate the physical qualities of soils. Standard classifications have been adopted to help engineers to talk the same soil language. There is great need for the correlation of this work with the structural qualities or bearing power of the various soils.

The variation of subgrade supporting power has a pronounced effect on the relation in thickness of flexible and rigid pavements to develop the same load-carrying capacity. Tests made at the Illinois Bates Test Road and at the Bureau of Public Roads show that a given load, transmitted through equal thicknesses of flexible and rigid pavements, results in a subgrade pressure under the flexible type that is eight times as great as under the rigid type. Further, the load is distributed over a relatively small area under the flexible type and over a relatively large area in the case of the rigid pavement. (See "Interrelationship of Load, Road and Subgrade" by C. A. Hogentogler, *Public Roads*, May, 1929, pp. 37-64.)

Consequently it may be said that the weaker the subgrade, the greater must be the relative thickness of flexible to rigid pavements to develop the same load-carrying capacity; and, conversely, the stronger the subgrade, the nearer this relationship approaches unity.

Experience and common sense both support these tests and this conclusion. Fortunately there are available reliable formulas or analyses for evaluating these factors in making comparable designs.

## Design of flexible types

As previously stated, a pavement of the flexible type has no flexural, beam or slab strength but relies on the interlocking of the aggregate to distribute the wheel-load pressures as they occur on the pavement surface down to the subgrade proper. The amount of distribution of this pressure is dependent upon the thickness of the base, and the total thickness of such roads must be adequate to reduce the subgrade pressures to an amount that the soil is capable of carrying. Unless this is done, the subgrade depresses or flows laterally, the surface becomes depressed, high impact stresses occur, and the road is rapidly destroyed.

There are three formulas for thickness of the pavements which have been developed during the years and which give results that closely agree and that also agree with the behavior of such pavements under traffic. These formulas are as follows:

*Harger and Bonney*—These authorities present the formula:

$$D = \sqrt{\frac{W}{3P} + \frac{T^2}{9}} - \frac{T}{3}$$

in their "Hand Book for Highway Engineers," 1927, pp. 366-425, in which $D$ = the depth of pavement in inches; $W$ = the wheel load in pounds, including impact; $T$ = the tire width in inches; and $P$ = the maximum pressure on the subgrade in pounds per square inch.

Applying this formula and assuming $T = 10$ in., $P = 10$ lb. per sq.in. and $W = 12{,}000$ lb. (8,000-lb. static load plus 50 per cent impact), we compute:

$$\begin{aligned} D &= \sqrt{\frac{12{,}000}{3 \times 10} + \frac{10^2}{9}} - \frac{10}{3} \\ &= \sqrt{411.11} - 3.33 \\ &= 16.95 \text{ in.} \end{aligned}$$

Using $P = 20$ lb. per sq.in., we compute $D = 11.20$ in.

Harger and Bonney's book also quotes a statement made by W. E. McClintock, chairman of the Massachusetts Highway Commission, which is as follows: "The commission has estimated that non-porous soils, drained of groundwater, at their worst will support a load of 4 lb. per square inch. On sand or gravel, the pressure can safely be put at 20 lb. per square inch."

*Massachusetts*—The Massachusetts highway department formula as given by Professor C. C. Wiley in his highway textbook, "Principles of Highway Engineering," is as follows:

$$T = \sqrt{\frac{W}{4P}}$$

Where $T$ = the pavement thickness in inches; $W$ = the wheel load in pounds, including impact; and $P$ = the allowable subgrade pressure in pounds per square inch.

Using a value of $W = 12{,}000$ and $P = 10$, as before, this formula gives

$$\begin{aligned} T &= \sqrt{\frac{12{,}000}{4 \times 10}} \\ &= \sqrt{300} \\ &= 17.3 \text{ in.} \end{aligned}$$

If $P$ is taken at 20 lb. per sq.in.,

$$\begin{aligned} T &= \sqrt{\frac{12{,}000}{4 \times 20}} \\ &= \sqrt{150} \\ &= 12.25 \text{ in.} \end{aligned}$$

*W. S. Downs*—In a recent statement to the federal coordinator of transportation, W. S. Downs, consulting engineer and professor of highway engineering, University of West Virginia, uses the following formula:

$$T = 0.564\sqrt{\frac{P}{S}}$$

in which $T$ = the pavement thickness in inches; $P$ = unit wheel load in pounds; and $S$ = the safe bearing power of the soil in pounds per square inch.

Using the value for subgrade pressure of 10 lb. per sq.in., this formula becomes

$$T = 0.564\sqrt{\frac{12{,}000}{10}}$$
$$= 19.45 \text{ in.}$$

If the subgrade pressure is taken at 20 lb. per sq.in.,

$$T = 0.564\sqrt{\frac{12{,}000}{20}}$$
$$= 13.8 \text{ in.}$$

A summary of the thicknesses determined by the foregoing calculations is shown in Table I.

TABLE I—THICKNESSES OF FLEXIBLE PAVEMENT FOR 8000-LB. STATIC LOAD + 50 PER CENT IMPACT

| Harger and Bonney |  | Wiley Mass. H'way. Dept. |  | Downs |  | Average |  |
|---|---|---|---|---|---|---|---|
| Subgrade Pressure Lb./Sq.In. |  | Subgr. Press. Lb./Sq.In. |  | Subgr. Press. Lb./Sq.In. |  | Subgr. Press. Lb./Sq.In. |  |
| 10 | 20 | 10 | 20 | 10 | 20 | 10 | 20 |
| 16.95 | 11.20 | 17.3 | 12.25 | 19.45 | 13.8 | 17.9 | 12.42 |

Of the above, the Harger and Bonney and Wiley formulas apparently have the most background. The Harger and Bonney is perhaps the most rational because it takes into account variations in tire width. Also this formula shows remarkable agreement with actual road experience. In the "Highway Engineers' Hand Book," Fig. 131, p. 388, is shown a graph on which are plotted successes and failures of flexible pavements actually observed over a sixteen-year period and also the curve representing the formula. The agreement of the successes with the formula curve is most convincing.

On the Bates Test Road in Illinois there were built and tested to destruction twelve variable-thickness flexible sections. Accurate records are available showing the number and weight of wheel loads applied and the observed behavior of the test sections under these loads. If we select the load under which incipient failure occurred and compute the corresponding subgrade pressure by the Harger and Bonney and Wiley formulas, we find that these computed pressures check very closely with the actual bearing value of the soil—namely 10 lb. per sq.in. This bearing value was determined in a large number of tests by loading a 3-ft. diameter block. The agreement of these formulas with the behavior of the test sections under actual traffic is most convincing (Table II).

In view of the foregoing discussion, the Harger and Bonney formula is recommended for design purposes. The proper bearing power for the subgrade must be determined, and this formula will then give the required center thickness. The edges will be the weak section of such a pavement. This may be overcome by extending the base beyond the limits of the travelled surface or by adequate edge thickening. (See Goldbeck's discussion in *The Crushed Stone Journal*, April and June issues, and also Harger and Bonney's "Highway Engineers' Handbook.")

## Design of rigid types

Since the Bates test road and other tests have shown that surfaces of asphalt, tar, bituminous-filled brick, etc., placed on a concrete base add practically no structural strength to the base, such a base should be designed in the same manner as a portland cement concrete pavement.

The most scientific method of analyzing stresses in concrete pavements is that produced by Dr. H. M. Westergaard, of the University of Illinois, and published in *Public Roads*, April, 1926, and December, 1933. Dr. Westergaard evaluates the variation in subgrade support in his formulas by means of the quantity $k$, which he terms the modulus of subgrade reaction. A value of $k$ equaling 100 means that the soil when loaded with 1 lb. per sq.in. will have a deformation of 1/100 in. This represents a relatively weak subgrade and corresponds to the black clay loam soil on the Illinois Bates Test Road, which had a deformation of 1/10 in. under 10 lb. per sq.in. The higher the value of $k$ the greater the subgrade support.

The stresses computed by the Westergaard method check closely with actual measured stresses, and consequently we can use this analysis to evaluate the effect of varying degrees of subgrade support.

Since the Westergaard analysis, involving the use of the calculus, seems rather formidable for routine use, the writer developed and published in the pamphlet, "Concrete Road Design, Simplified and Correlated in Traffic" some simple empirical formulas for stress analysis. (This pamphlet may be had on application to the Portland Cement Association, 33 West Grand Ave., Chicago, Ill.)

Space does not permit presentation of all the formulas and methods of design that are presented in this pamphlet. Therefore, the reader should refer to it to gain a complete understanding of this paper. The pamphlet contains a complete exposition of simple methods of stress analysis for uniform thickness, thickened edge and balanced-designed cross-sections. It further permits correlation of design with traffic expectancy. By invoking research data on the fatigue behavior of concrete under repeated stresses of various magnitudes, the expected number of the various-sized wheel loads may be used to select the proper safety factor that will result in the required structural life under the expected traffic. This permits major economies in designs for the lighter traffic and indicates the reserve strength against overloading characteristic of designs for heavy primary-road traffic having a safety factor of 2.

The methods used are fully backed up by extensive research work and actual behavior of pavements in service, and may be used with confidence. All stress formulas include an impact factor of 50 per cent.

These formulas are fully explained in the pamphlet described and are based on subgrade support corresponding to a value of $k$ = 100. They give stresses that check very closely with Westergaard's work and with actual measured stresses. Since they are based upon uniform but relatively weak subgrade, they would be ultra conservative when better soils are encountered.

This work has since been extended to the development of a series of coefficients to evaluate the variations in subgrade support; these modify the original formulas, which were predicated on $k$ = 100.

The original formula for pneumatic-tired vehicles and protected corners in "Concrete Road Design, Simplified and Correlated with Traffic" is,

$$S = \frac{1.92W}{d^2}$$

where $S$ = unit stress in pounds per sq.in.; $d$ = depth of slab in inches; and $W$ = wheel load in pounds (measured statically, but the formula automatically provides an impact allowance of 50 per per cent.).

To evaluate subgrade support, we may write this formula as follows:

$$S = \frac{1.92\,Wc}{d^2}$$

where $c$ is the coefficient of subgrade support.

The values of $c$ for variable subgrade support were accurately determined by means of the latest Westergaard analysis, and when used in Sheets' formulas will give stresses closely checking results secured by the more complicated Westergaard analysis. The values of $c$ corresponding to $k$ are as follows:

| Values of Modulus of Subgrade Reaction or Westergaard's $k$ | Corresponding Coefficient for Use in Sheets' Formulas $C$ |
|---|---|
| 50 | 1.096 |
| 100 | 1.000 |
| 200 | .900 |
| 300 | .842 |
| 400 | .800 |
| 500 | .770 |

The selection of the proper value for $k$ or corresponding $c$ may be based on judgment of the soil's supporting power, but preferably should be based on bearing-power tests as previously discussed.

With $c$ determined for a given road project, the remaining steps in design

## TABLE II—ANALYSIS OF BATES ROAD FLEXIBLE TYPE SECTIONS

**Roman figures** are for $p$ derived from Wiley's formula, and italic **figures** are for $p$ derived from Harger and Bonney formula.

| Section No. | Description | No. of Applications | Computed Subgrade Pressures, $p$ — Wheel Load, Lb. — Static | | Plus 25% Impact | | Plus 50% Impact | | Behavior of Road |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 3-in lug brick—bit. filler<br>2-in. sand cushion—4-in. stone base<br>$T$ = 9 in. | 1,000 | 2,500<br>$p$ = 7.73 | *5.9* | 3,120<br>9.63 | *7.4* | 3,750<br>11.6 | *8.9* | Serious distress |
| | | 3,200 | 3,500<br>$p$ = 10.8 | *8.3* | 4,370<br>13.5 | *10.3* | 5,250<br>16.2 | *12.4* | Bad failure |
| 1B | 3-in. lugless brick—bit. filler<br>2-in. sand cushion—4-in. stone base<br>$T$ = 9 in. | 1,000 | 2,500<br>$p$ = 7.73 | *5.9* | 3,120<br>9.63 | *7.4* | 3,750<br>11.6 | *8.9* | Serious distress |
| | | 3,200 | 3,500<br>$p$ = 10.8 | *8.3* | 4,370<br>13.5 | *10.3* | 5,250<br>16.2 | *12.4* | Bad failure |
| 2 | 4-in. lug brick—bit. filler<br>2-in sand cushion—4-in. stone base<br>$T$ = 10 in. | 1,000 | 2,500<br>$p$ = 6.3 | *5.0* | 3,120<br>7.8 | *6.2* | 3,750<br>9.4 | *7.5* | Serious distress |
| | | 3,200 | 3,500<br>$p$ = 8.8 | *7.0* | 4,370<br>10.9 | *8.7* | 5,250<br>13.2 | *10.5* | Bad failure |
| 3 | 4-in. lugless brick—bit. filler<br>2-in. sand cushion—4-in. stone base<br>$T$ = 10 in. | 1,000 | 2,500<br>$p$ = 6.3 | *5.0* | 3,120<br>7.8 | *6.2* | 3,750<br>9.4 | *7.5* | Serious distress |
| | | 3,200 | 3,500<br>$p$ = 8.8 | *7.0* | 4,370<br>10.9 | *8.7* | 5,250<br>13.1 | *10.5* | Bad failure |
| 4 | 3-in. lug brick—1-in. mastic cushion—8-in. stone base<br>$T$ = 12 in. | 1,000 | 2,500<br>$p$ = 4.3 | *3.7* | 3,120<br>5.4 | *4.6* | 3,750<br>6.5 | *5.6* | Incipient failure |
| | | 3,200 | 3,500<br>$p$ = 6.1 | *5.2* | 4,370<br>7.6 | *6.5* | 5,250<br>9.1 | *7.8* | Serious distress |
| | | 3,000 | 4,500<br>$p$ = 7.8 | *6.7* | 5,630<br>9.8 | *8.4* | 6,750<br>11.7 | *10.0* | Bad failure |
| 5 | 3-in. lugless brick—1-in mastic cushion—8-in. stone base<br>$T$ = 12 in. | 1,000 | 2,500<br>$p$ = 4.3 | *3.7* | 3,120<br>5.4 | *4.6* | 3,750<br>6.5 | *5.6* | Incipient failure |
| | | 3,200 | 3,500<br>$p$ = 6.1 | *5.2* | 4,370<br>7.6 | *6.5* | 5,250<br>9.1 | *7.8* | Serious distress |
| | | 3,000 | 4,500<br>$p$ = 7.8 | *6.7* | 5,630<br>9.8 | *8.4* | 6,750<br>11.7 | *10.0* | Bad failure |
| 6 | 2-in. Topeka top<br>2-course stone base 10-in. thick<br>$T$ = 12 in. | 1,000 | 2,500<br>$p$ = 4.3 | *3.7* | 3,120<br>5.4 | *4.6* | 3,750<br>6.5 | *5.6* | No damage |
| | | 3,200 | 3,500<br>$p$ = 6.1 | *5.2* | 4,370<br>7.6 | *6.7* | 5,250<br>9.1 | *7.8* | Incipient failure |
| | | 3,000 | 4,500<br>$p$ = 7.8 | *6.7* | 5,630<br>9.8 | *8.4* | 6,750<br>11.7 | *10.0* | Bad cracks—some broken areas |
| | | 3,000 | 5,500<br>$p$ = 9.5 | *8.2* | 6,880<br>11.9 | *10.2* | 8,250<br>14.3 | *12.3* | Serious distress |
| | | 3,000 | 6,500<br>$p$ = 11.3 | *9.7* | 8,130<br>14.1 | *12.1* | 9,750<br>16.9 | *14.5* | Bad failure |
| 7 | 2-in Topeka top<br>2-course, 8-in. stone base<br>$T$ = 10 in. | 1,000 | 2,500<br>$p$ = 6.3 | *5.0* | 3,120<br>7.8 | *6.2* | 3,750<br>9.4 | *7.5* | No damage |
| | | 3,200 | 3,500<br>$p$ = 8.8 | *7.0* | 4,370<br>10.9 | *8.7* | 5,250<br>13.1 | *10.5* | Incipient failure |
| | | 3,000 | 4,500<br>$p$ = 11.2 | *9.0* | 5,630<br>14.1 | *11.3* | 6,750<br>16.9 | *13.5* | Bad cracks and broken areas—Serious distress |
| | | 3,000 | 5,500<br>$p$ = 13.7 | *11.0* | 6,880<br>17.2 | *13.8* | 8,250<br>20.6 | *16.5* | Bad failure |
| 8 | 1½-in. Topeka—1½-in. bit. binder<br>5-in. stone<br>$T$ = 8 in. | 1,000 | 2,500<br>$p$ = 9.8 | *7.1* | 3,120<br>12.2 | *8.9* | 3,750<br>14.7 | *10.7* | No damage |
| | | 3,200 | 3,500<br>$p$ = 13.7 | *9.9* | 4,370<br>17.1 | *12.4* | 5,250<br>20.5 | *14.9* | Incipient failure |
| | | 3,000 | 4,500<br>$p$ = 17.6 | *12.8* | 5,630<br>22.0 | *16.0* | 6,750<br>26.4 | *19.2* | Progressive incipient failure |
| | | 3,000 | 5,500<br>$p$ = 21.4 | *15.6* | 6,880<br>26.8 | *19.5* | 8,250<br>32.2 | *23.5* | Continued serious distress |
| | | 3,000 | 6,500<br>$p$ = 25.4 | *18.5* | 8,130<br>31.8 | *23.1* | 9,750<br>38.1 | *27.7* | Bad failure |
| 9 | 2-in. Topeka top<br>6-in. stone base<br>$T$ = 8 in. | 1,000 | 2,500<br>$p$ = 9.8 | *7.1* | 3,120<br>12.2 | *8.9* | 3,750<br>14.7 | *10.7* | No damage |
| | | 3,200 | 3,500<br>$p$ = 13.7 | *9.9* | 4,370<br>17.1 | *12.4* | 52.50<br>20.5 | *14.9* | Incipient failure |
| | | 3,000 | 4,500<br>$p$ = 17.6 | *12.8* | 5,630<br>22.0 | *16.0* | 6,750<br>26.4 | *19.2* | Progressive serious distress |
| | | 3,000 | 5,500<br>$p$ = 21.4 | *15.6* | 6,880<br>26.8 | *19.5* | 8,250<br>32.2 | *23.5* | Continued serious distress. (Next load 6,500—bad failure) |
| 10 | 2-in. Topeka top<br>4-in. Novaculite base | 1,000 | 2,500<br>$p$ = 17.4 | *11.0* | 3,120<br>21.6 | *13.7* | 3,750<br>26.0 | *16.4* | Serious failure—Failed after a very few load applications |
| 11 | 2-in. Topeka top<br>4-in. Stone base<br>$T$ = 6 in. | 1,000 | 2,500<br>$p$ = 17.4 | *11.0* | 3,120<br>21.6 | *13.7* | 3,750<br>26.0 | *16.4* | Serious distress—Bad failure after a few repetitions of load |
| | | 3,000 | 3,500<br>$p$ = 24.3 | *15.4* | 4,370<br>30.4 | *19.2* | 5,250<br>36.5 | *23.0* | Very bad failure |

may follow the principles set forth in the writer's pamphlet heretofore mentioned.

In order to make designs of rigid and flexible pavements that have equal load-carrying capacity for a given soil or subgrade condition, it is obvious that the proper correlation of the abovementioned factors and *b*, the allowable subgrade pressure given by Harger and Bonney, is necessary.

Fortunately we are not in the dark on this. In the case of the Bates road soil, Westergaard's *k* is equal to 100. Sheets' corresponding coefficient *c* is 1.00. This is proved by the fact that Sheets' stress analysis and Westergaard's analysis both agree and also check very closely actual measured stresses. Further, the concrete slabs behaved exactly as the stress formulas indicated they should under actual traffic tests. Also the bearing power of this soil was such that a pressure of 10 lb. per sq.in. resulted in a soil deformation of 1/10 in. The computed pressure by Harger and Bonney formula, at the time of incipient failure of the flexible sections, was very close to 10 lb. per sq.in. Here is an almost perfect correlation of these factors.

Further, recent investigations on an entirely different clay soil indicate a value of $k = 200$. The bearing power of this soil was such that at 20 lb. per sq. in. there was a deformation of approximately 1/10 in., when the soil was loaded by means of a 3-ft.-diameter plate. Here again the same relationship apparently exists.

It, therefore, seems highly probable that much higher values of *k* will occur on the more stable soils, and that the same general relationship between *k* and bearing power will prevail in the upper values.

We may therefore feel reasonably sure in assuming for design purposes the relationships indicated in Table III.

TABLE III—EFFECT OF SOIL ON BEARING POWER

| Nature of Subgrade | Bearing Power Lb. Per Sq.In. | Corresponding Value of *k* for Use in Westergaard's Formulas for Concrete Slab Design | Corresponding Value of *c* for Use in Sheets' Formulas for Concrete Slab Design |
|---|---|---|---|
| Very soft and plastic | 5 | 50 | 1.096 |
| Soft and plastic | 10 | 100 | 1.000 |
| Fairly hard | 20 | 200 | .900 |
| Hard | 30 | 300 | .842 |
| Very hard | 40 | 400 | .800 |
| Extremely hard gravel or macadam | 50 | 500 | .770 |

Even though the higher values indicated in the table may subsequently be shown to require adjustment, no serious change in thickness ratios between flexible and rigid pavements would result. The extreme range in center thickness of concrete between $k = 50$ and $k = 500$ for a given frequency of maximum wheel load is about 1 in., whereas computations show a wide range in required thicknesses for the flexible types. Results of design computations, using these formulas and indicated values, are reasonable and well in accord with observed actual road behavior.

However, the writer does not presume to set these value as the final answer. They represent the best available knowledge and are presented as a rational guide for economical and comparable design of pavements.

## Safety and impact factors

It is obvious that Westergaard's *k* or the coefficient *c* as determined for a given subgrade affect the amount of stress resulting from a specific load applied to a given thickness of rigid pavement. The safety factor of the design used will depend upon the allowable concrete working stress assumed, which in turn should be a function of the traffic expectancy and required structural life. For example, if the ultimate modulus of rupture of the concrete is 700 lb. sq.in. and the working stress is 350 lb. per sq. in., the safety factor will be 2. We may vary the safety factor by varying the allowable working stress, and the proper method of doing this is explained in the pamphlet heretofore described.

However, if we use the full bearing power of the soil as the allowable pressure in applying the Harger and Bonney or other formulas to the design of flexible pavements, we will have a safety factor of only 1. For proper stability, long life and reasonable maintenance cost, a larger safety factor or lower allowable pressure should be used. For comparable designs in rigid and flexible pavements the safety factors should be approximately equal.

Extensive researches on the subject of impact resulting from moving loads, made by the Illinois Highway Department and the Bureau of Public Roads, indicate that at common road speeds the allowance for impact in the range of wheel loads affecting design should be 50 per cent of the static wheel load. In other words, the static load should be increased by 50 per cent for design purposes. This is common practice throughout the country, and impact cannot be lightly dismissed.

In applying Westergaard's analysis to design, a 50 per cent impact factor should be used. The writer's empirical formulas by the coefficients used include the same factor, although the static load is used as the value of *W* in the formulas. This is proved by the fact that stresses so computed check with stresses computed by the Westergaard analysis with 50 per cent impact allowance added to the static wheel load.

The same allowance for impact should be made in designing flexible pavements. Unless they remain very smooth, the actual impact may be greater. This statement is borne out by the behavior of the flexible sections on the Bates test road, where the computed pressure by the Harger and Bonney formula with 50 per cent impact allowance agreed with the measured bearing power of the soil at the time of incipient failure of the test sections under applied moving loads. Continuation of this load or a slight increase in weight completely destroyed them.

## Practical considerations

Some interesting possibilities in design of rigid and flexible types present themselves. A few calculations will show that on soils of low supporting power the required thickness of flexible types is much greater than for concrete. Suppose, for example, that a plastic black clay loam subgrade with a supporting value of 10 lb. per sq. in. is under consideration. These alternate courses are available.

1. Design the flexible type with appropriate safety factor on the basis of the original soil.
2. Stabilize the original subgrade by adding granular or other materials and determine the resulting bearing power. Design the thickness of flexible type on this revised subgrade basis, using an appropriate safety factor. In this case, however, the cost stabilization must be charged to the construction cost.
3. Design the concrete slab or rigid type on the basis of the original subgrade with a bearing power of 10 lb. per sq. in. $k = 100$ or $c = 1.00$.
4. Design the concrete on the basis of the stabilized subgrade using proper value of *k* or *c*. In this case the cost of subgrade treatment must be included.

With this accomplished, the engineer may then determine the relative cost of these methods for each type and select for each type the most economical design for the soil condition.

## Special subgrade conditions

In a general paper it is impossible to discuss all the special conditions of subgrade that may arise. For example, certain clay and adobe soils are subject to great volume change with varying moisture contents. Also certain soils that take up moisture freely experience large volume changes when frozen. In either case serious distress results in the superimposed pavement—whether rigid or flexible.

The cure lies not in abandoning well-established principles of pavement design but in striking at the root of the trouble, and by proper methods of subgrade treatment correcting the unstable subgrade condition. Then we may design on the basis of the corrected subgrade values.

From the foregoing discussions it becomes evident that we must come more and more to evaluate subgrades as a design factor. Tests of both the physical properties and structural behavior of subgrades should become a routine function of the highway engineer. Determinations of bearing powers and values of $k$ or corresponding $c$ are not unduly difficult, and standardized methods will reduce them to simple operations. As rapidly as possible such tests should become the fundamental basis for scientific highway design.

## Comparable designs

In Table IV is presented an illustration of comparable designs based on various degrees of subgrade support, for an *unlimited number* of repetitions of a 9,000-lb. pneumatic-tired, static wheel load with a 50 per cent allowance for impact. This is typical primary-road traffic. The Harger and Bonney formula was used for flexible pavement design.

The computed thicknesses shown in the foregoing table may, on first inspection, appear to be somewhat high for the flexible pavements. It should be borne in mind that the traffic on which these designs are based is heavy primary road traffic, involving a high frequency of heavy wheel-loads.

The Bates road test, conducted in Illinois some years ago, throws light on this. The table, herein given, shows that even the heaviest flexible-type sections failed under a relatively few applications of a 6,500-lb. solid-rubber-tired wheel load, and that they showed serious distress under much lighter loads. The subgrade was a black clay loam soil having a bearing value of 10 lb. per sq. in.

On the other hand, the rigid sections, built on the same subgrade, having a center thickness of 6 in. with appropriate edge thickness, withstood a large number of 8,000-lb. solid-rubber-tired moving wheel loads without distress and carried much higher loads before first signs of distress appeared.

## Economic comparisons

Once the most economical design for each type has been determined, economic comparisons should be made to guide final selection of the design for the project under consideration. This involves the following simple steps.

1. Determine the first cost of each type from engineer's estimates or by taking competitive bids.

2. The total annual cost of transportation for each type may then be determined, following widely accepted common-sense methods. Such determinations should be made for some definite period, say 20 years.

*The total annual cost of transportation* is composed of the sum of two elements: (*a*) the annual road cost; and (*b*) the annual cost of operating vehicles on the road surface.

*Annual road costs* are composed of the following elements: (*a*) investment charges, (*b*) interest charges, (*c*) maintenance charges (including periodic repairs), the sum of which constitutes the annual road cost.

TABLE IV—COMPARABLE DESIGNS FOR VARIOUS SUBGRADES

| General Nature of Subgrade | Actual Bearing Power, Lb. per sq.in. | Corresponding Westergaard $k$ | Corresponding Coefficient for Sheets' formulas $c$ | Designed Center Thickness in Inches for Unlimited Number 9000-Lb. Wheel loads + 50 per cent impact: Flexible Safety Factor 1 | Pavement Safety Factor 2 | Rigid Pavement Safety Factor 2 |
|---|---|---|---|---|---|---|
| Very soft and plastic | 5 | 50 | 1.096 | 26.85 | 39.22 | 6.25 |
| Plastic (such as black clay loam of Bates test road) | 10 | 100 | 1.000 | 18.14 | 26.85 | 6.00 |
| Fairly hard | 20 | 200 | .900 | 12.03 | 18.14 | 5.67 |
| Hard | 30 | 300 | .842 | 9.36 | 14.30 | 5.48 |
| Very hard | 40 | 400 | .800 | 7.79 | 12.03 | 5.34 |
| Compacted gravel, etc. | 50 | 500 | .770 | 6.72 | 10.50 | 5.24 |

Algebraically this is best stated in the following formula by Prof. C. B. Breed, of Massachusetts Institute of Technology, on p. 94 of the Thirteenth Annual *Proceedings* of the Highway Research Board:

$$C = \frac{A - S}{n} + \frac{A + S}{2} r + B + \frac{E}{n}$$

in which C = average annual road cost, A = original capital cost, B = annual maintenace cost, $r$ = rate of interest, $n$ = estimated life or (assumed period for comparison of alternate types), $S$ = salvage value at end of $n$ years, and $E$ = any periodic maintenance during life $n$.

The formula is sufficiently accurate for all practical purposes, is easily applied, readily comprehended by the average layman and is recommended for general use.

*Annual cost of vehicle operation* depends upon the number of motor vehicles and the type of the road surface. Engineering research conducted by Dean Agg of the Iowa Engineering Experiment Station, reported in the bulletins of the Iowa Engineering Experiment Station and in the *Proceedings* of the Highway Research Board, has revealed the average cost of motor-vehicle operation on various road surfaces. Then the annual cost of motor-vehicle operation would be:

365 days) × (number of vehicles per day) × (cost per mile of vehicle operation)

As above indicated, adding the *annual road cost* and the *annual cost of vehicle operation* gives the *annual cost of transportation* for each type.

3. Compare the *annual cost of transportation* on each type of road. The type having the lowest figure will be the best road purchased for the specific case, provided the foregoing steps have been followed.

## Conclusion

In the foregoing pages there have been outlined certain principles that are well established and widely supported. Every effort has been made to represent this problem in its true light. Some original, but well supported, material has been included. It is believed that the methods proposed are conservative and merit serious consideration. Such questions as are not fully answered become a challenge for research and investigation leading to complete rationalization of highway design.

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# 5...Bridge Design

### *J. R. Burkey*

PROVISION for future vehicle speeds and frequencies indicates consideration of the bridge as a continuation of the roadway in travel width and unbroken profile • Visualizing the structure as a whole, this discussion points out new design problems and their solution.

TO ONE who has watched the developments of the motor vehicle with its tremendous increase in weight, size and speed, there is a certain hesitancy in presuming to outline what demands this transport agency may make on our bridges of the future. It is particularly difficult to center one's thought on the needs of the coming years when the present bears witness to such inadequacies as exist on the structures of our highways that demand immediate attention. The accompanying photograph of a pin map shows the weak and narrow bridges on the state highway system of Ohio. Some 2,000 pins indicate the location of bridges, large and small, which, due either to their weakness or narrowness or both, are inadequate to serve safely the traffic that operates legally on our highways today. The first consideration, therefore, which is recommended in looking to the handling of our future bridge problem, is to obtain a true picture of what we now have, and with that as a starting point, to plan constructively for all reasonable future needs.

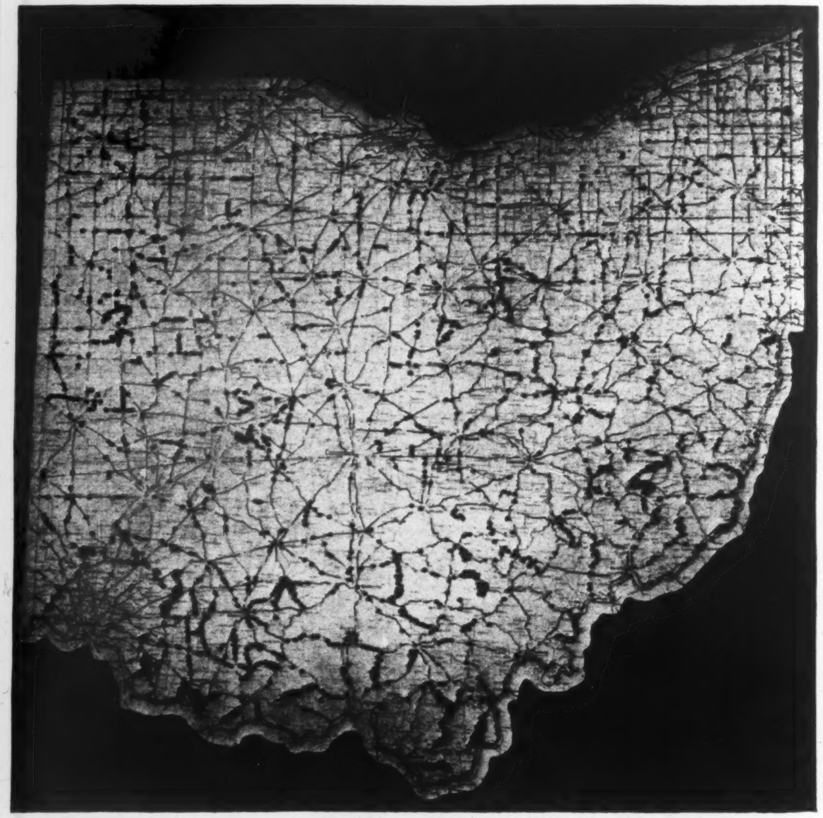
## New problems arising

In the days of the oxcart, it was customary to build most bridges at right angles to the streams for the sake of simplicity and economy. Today, the volume and speed of traffic and the demand for the shortest possible routes on our utility highways require that the highway bridge be adapted to the traffic needs, even though this may bring to the bridge engineer all of the complexities of skew, gradient, curve and superelevation, which delete the word symmetry from his vocabulary and multiply his difficulties and chances for error many times. Future traffic on our main arteries of travel will demand bridges that fulfill all reasonable requirements in the matter of alignment, gradient, sight distances and clearances, lateral clearances in particular, which contemplate faster-moving vehicles.

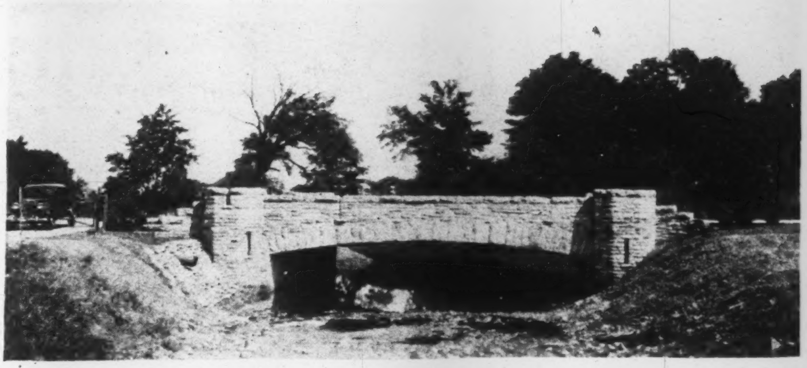
Aside from our main arterial highways, a large problem will be involved in the development of less pretentious, perhaps, but adequate structures, on the many miles of local highways serving small communities. Present studies by those concerned with the welfare of our people point to the decentralization of our large industrial communities and the bringing of industry to the smaller settlements where people can live more cheaply with a fuller enjoyment of life's opportunities. This bids fair to be more than a dream; and when that time comes, commercial haul will rely more and more on highway facilities, the building of which will tax the ingenuity of the bridge engineer to provide the great number of structures that will be needed with the funds available for that purpose.

## New aids developing

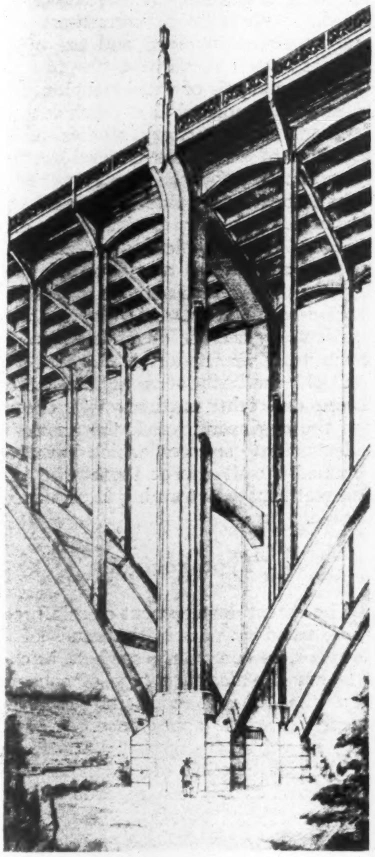
Recent years have brought forth many new and improved materials and facilities for design and construction which will doubtless have a great influence on the bridge structure. Perhaps the most notable recent development likely to have a marked influence on the bridge of the future is the art of metal welding. This process of fabricating



**A PIN MAP shows some 2,000 weak and narrow bridges on the state highway system of Ohio, which are inadequate to serve safely the traffic operating legally on our highways today.**



**THE RIGID FRAME** has acquired acceptance rapidly as engineers have become conversant with its design principles and the opportunities which it affords.



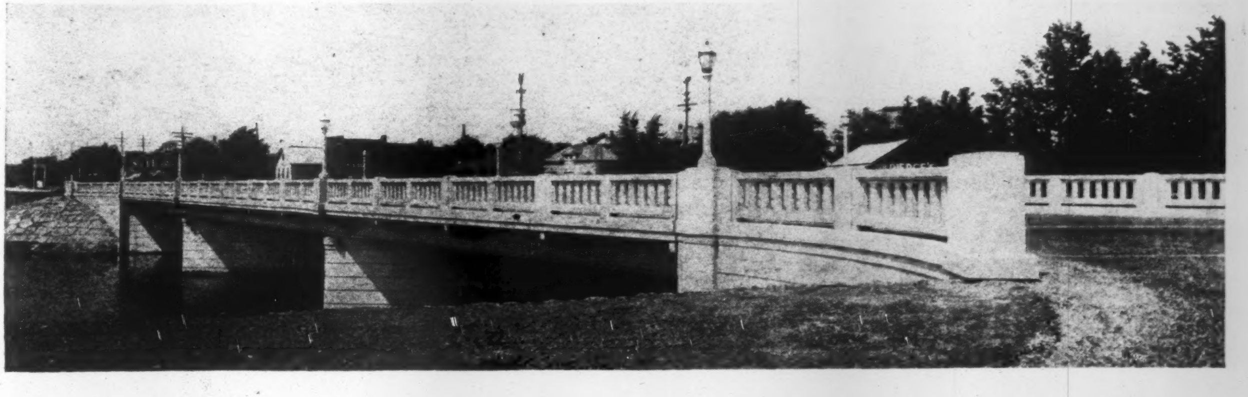
**WELDING** affords an almost unlimited opportunity in the creation of lines and shapes in the esthetic development of a structure. This sketch was prepared from plans of a welded and riveted viaduct recently placed under contract near Cleveland by the Ohio state highway department.

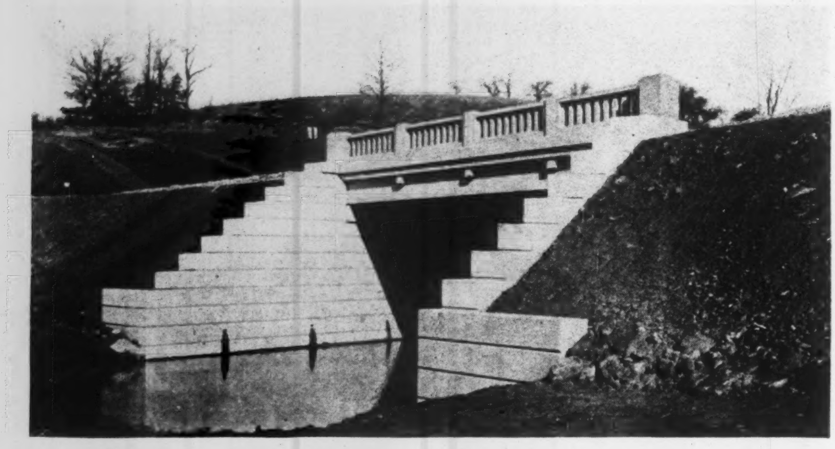
structural steel in particular, is gaining rapid headway and will no doubt have a decided influence not only on the methods of design, fabrication and erection of our structures, but upon the architectural appearance as well. It will require some time to coordinate theory and practice as regards this relatively new process, but rapid strides are being made at the present time, and when we are once assured of a uniform homogeneous welded joint the obvious advantages of this process will undoubtedly promote its widespread use. Loss of section due to rivet holes will be avoided, and the opportunity of eliminating or reducing the size of awkward and extensive gusset plates at joint connections will be welcomed by all designers. Then too, the carrying of the uniform section into the very heart of the joint simplifies the distribution of stress at the joint to such an extent that the determination of secondary stresses can be accomplished with confidence and an ease that will tend to make this procedure quite general. Welding affords the engineer an almost unlimited opportunity in the creation of lines and shapes in the development of a structure.

Higher-strength steel and its alloys, the use of which is generally confined now to structures of outstanding magnitude, may be expected to become more commonly used as the cost of special steels becomes less. Non-corrosive and corrosion-resisting alloys have already been used for structural and architectural details and may be expected to be more generally used as new alloys are developed and their cost reduced.

Concrete bridges, which have seen such rapid development in the last quarter century, will doubtless continue in the majority in the building of spans of reasonable length. While the bridge engineer will be ever conscious of the need of as great strength as possible in the concrete that makes up these structures, greater emphasis will be placed upon the unquestioned dependability of each and every cubic foot of such masonry as is built. This will mean closer control of all of the materials and a strict adherence to the principle of a low water-cement ratio. The placing of concrete will become a still more responsible operation, utilizing all of the processes that will improve the density of the concrete, and gradually eliminating all of those that contribute to a lack of uniformity in the finished product. In other words, it is likely that density and durability will receive added emphasis, and, along with strength, will

**WIDE-FLANGED ROLLED-STEEL GIRDERS** make it possible to increase our span lengths and at the same time maintain comparatively shallow decks, for the better accommodation of waterways. This type of structure also adapts itself to continuous spans.





**STRAIGHT ABUTMENTS** with stepped walls, to retain the roadbed slopes and inexpensive turnback wings, to retain the toe of the embankment and to prevent erosion, are elements of a design that permits easy widening with increasing traffic.

be the chief qualities sought for in our structural concrete. Further studies of cement itself may contribute largely to the ultimate answer to this problem.

### Visualizing structure as a whole

While the foregoing comments regarding the concrete structure have to do primarily with materials and their field manipulations, it is becoming increasingly apparent that the designer of the future must approach his problem in a more thoughtful mood than he has in the past. A comprehensive study made recently by the Portland Cement Association clearly indicates that the designers of structures now built have too frequently failed to visualize the function of the structure as a whole. This study truthfully points out that many local failures that have occurred in our bridges reflect no shortcoming in the material itself, but incriminate those who failed to proportion and reinforce the structure to withstand the somewhat indeterminate stresses that occur in actual service. This applies particularly to abutments, and rather markedly to skewed bridges.

From another viewpoint, there is justification for further study of the behavior of the bridge as a whole. An open-spandrel arch, for instance, is designed as if the loads were transmitted directly to the arch ribs through members that could take no bending or would offer no resistance in themselves to the deformation of the arch. A careful comparison of the stresses in such an arch, when loaded with given suspended loads and when loaded with similar intensities applied on the top of the deck which was cast monolithically with the arch ribs, indicates that the stiffening effect of the deck materially reduces the stresses in the arch rib from those obtained by usual assumptions, and induces stresses in the deck itself, which are beyond those for which it would normally be designed unless this monolithic action is taken into account. Thus far it has been too much work or has involved too high technical skill on the part of the engineer to determine the behavior of the structure as a whole when supporting the loads for which it is designed. Certainly the devoting of more professional time to the study of this and kindred problems will create more work for the structural engineer, work which should pay large dividends in economies and a better-balanced design.

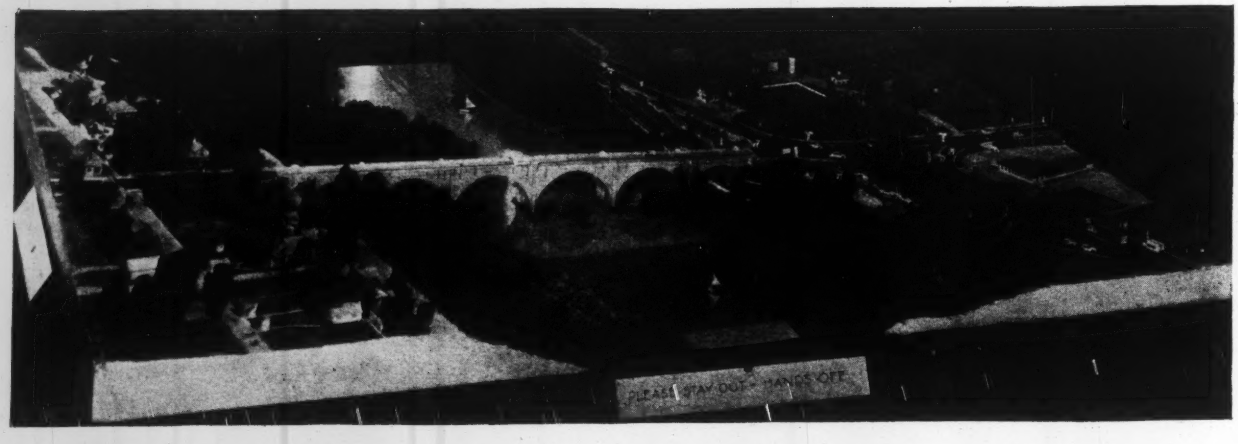
For the smaller structure a further recognition of the principles of the rigid frame wherein the horizontal thrust of the retained earth is used to assist in supporting the loads that come upon the span will certainly develop as engineers become more conversant with the principles involved and the opportunities which it affords.

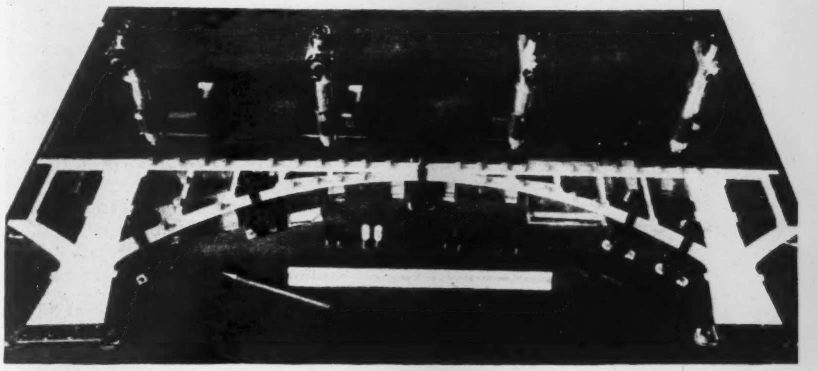
In the analysis of these complex problems, it is predicted that much use will be made of laboratory studies of the behavior of structures under load. Results obtained by the use of polarized light indicate that this may enable the structural engineer to determine quite reliably the complex distribution of stresses and afford a substantial check for any theory that may be evolved for their determination. The study of these problems by the use of models has done much to give confidence in both new and old methods of analytical attack. These and other methods will encourage the engineer to seek the answer to indeterminate stresses, which have been shunned by all except those who have had mathematical training to an unusual degree.

### Type revivals

The recent development of reinforced-brick masonry puts in the hands of the designer, in communities where brick is a common material, a type of construction that should commend itself for durability and appearance. Extreme care in workmanship will be necessary in the construction of this type of design, particularly as regards the en-

**MODELS** of a proposed bridge and the adjacent landscape are helpful design aids. Aerial photography can be employed to great advantage in portraying existing conditions.





**STUDY OF STRUCTURAL MODELS** has done much to give confidence in both new and old methods of analytical attack.

velopment of the reinforcing steel. Perhaps specially shaped reinforcement will be developed as most suitable for use in the mortar joints. Studies now in progress give promise of the development of brick units of one-man size, which will lessen the cost and afford greater opportunity for architectural treatment.

Stone masonry is likely due for increased use, particularly as a facing for structures of a monumental character or in locations where the use of this material is reasonably economic and especially fits into the landscape. It seems that this material would be very appropriate in the compression areas of reinforced masonry in a manner similar to that which is being developed for brickwork, although lack of uniformity in size of units will doubtless limit the placing of reinforcing in the stone masonry itself.

A certain revival is also to be expected in the use of structural timber, particularly for low-cost bridges on feeder or local roads or on stretches of important highways where major changes in location are contemplated at a reasonably early date. Except for those structures where the need of life is short, it is generally advisable to treat the timber with some preservative that will insure a much greater length of service. In certain locations the timber bridge lends itself admirably to a rustic treatment, which fits well into the landscape.

In these days so much of our travel is spent in search of recreation that it is highly important that our bridges be designed with an eye for beauty, especially when it can be obtained with very little additional cost. In considering roadside beautification and recreational opportunity, few places will be found along the highway that compare with those spots where the road and river meet. It follows then that our bridges should be so conceived as to harmonize with the natural beauty of our stream crossings. With such a wide variety of suitable materials, multiplicity of types and opportunities for landscape treatment, supplemented by the natural reflection of water, the bridge engineer should be able to meet this challenge. Much criticism has been heaped upon him in the past for apparent indifference or inability to create a structure of pleasing appearance, but a glance at some of the more recent structures will convince the most skeptical that the cultural aspect of our bridges is receiving much greater consideration.

**NEW EQUIPMENT** for foundation tests and a better understanding of soil mechanics will do much toward the elimination of substructure failures.

A scaled model of a proposed bridge and the adjacent landscape is quite helpful in working out a difficult situation and showing the new improvement in relation to surrounding property. Aerial photography can be employed to great advantage in portraying existing conditions.

If we are agreed that our structures are focal points in the beauty of our highways, it must be recognized that this architectural fitness cannot be obtained by the standardization of our plans. Excepting the strictly utilitarian structure, each bridge should be designed having in mind the special problem of the particular location and the justifiable architectural treatment that can be given to it. The sodding and planting of the roadway slopes adjacent to the stream bank add much to the beauty of the structure and frequently yield large returns in reduced maintenance cost that would otherwise result from erosion.

Except in special locations, the railings and other parts of superstructures above the roadway are viewed more critically by the traveling public than any other portion of our bridge structures. These portions of the bridge should, therefore, receive special consideration, and a variety provided if the full cultural value of our bridges is to be obtained. In Ohio, we have for several years endeavored to vary the structures on our highways and particularly to avoid the repetition of railings or superstructures that are alike.

Where bridges are located in or adjacent to built-up communities or public institutions such as schools and churches, provision should be made for the safety of pedestrian traffic by the building of sidewalks or what might be more appropriately termed "refuge walks."

On all important highways, through-types of bridges should be avoided wherever possible. The use of recently developed wide-flanged rolled-steel girders makes it possible to increase our span lengths and at the same time maintain comparatively shallow decks for the better accommodation of waterways. Spans of still greater length can be designed by using split sections for flanges and adding such depth of web as may be desired. If the appearance of rivets is considered objectionable in such cases, welding affords an opportunity for the development of connections. This type of structure adapts itself to continuous spans, varying the depths of girders, thus adding to the beauty of the structure and better proportioning it to meet the stresses to which it is subjected. Another decided advantage of this type of construction is the opportunity to provide continuous floor slabs, introducing expansion joints as infrequently as possible, thus holding to a minimum these joints which have too frequently been the point of attack for disintegration due to the seepage of water. For such structures, straight abutments are recommended with stepped walls to retain the roadbed slopes. Carefully placed riprap or inexpensive turnback wings can be used at the ends to retain the toe of the embankment and prevent erosion. The obvious advantage of such a design lies in the facility with which the bridge may be widened when increasing traffic so demands.

### Designing foundations

There is no phase of the bridge problem which troubles the designer and builder more than the foundation upon which the structure rests. Masterful studies have been under way and great progress has been made in furthering our knowledge of soil mechanics. The theory of this study still baffles the average engineer, but it is believed we may soon expect the results of these studies to be coordinated and expressed in a practical manner that will be of inestimable value to the bridge engineer.

It is becoming common practice to use bearing piles where yielding or penetrable foundation soils exist. Uncertainty as to the length of pile required to provide the necessary bearing has always been an embarrassment to the designing engineer. To shed more light on this subject, a cooperative project has been under way between the Bureau of Bridges of the Ohio Department of Highways and the Engineering Experiment Station of Ohio State University. In carrying on this study involving "the determination of the requirements for piling," a machine has been designed which sounds a proposed foundation site by means of driving a steel rod, measuring its penetration when driven by a known force, and is equipped to supplement this information by knowledge as to the force required to extract the rod. The machine also takes cores of the encountered material, which are studied in the soils laboratory to determine their characteristics. This research project, the report of which will soon be available in bulletin form, gives promise of helpfulness to the designer in predetermining the need for piling, and, in case it is used, the length that will be required. The development of new equipment for foundation tests and a better understanding of soil mechanics will do much toward the elimination of substructure failures.

### Changes in loadings

The loadings to which our trunk-line highway structures are subjected have experienced a rapid increase in recent years. In the early days of highway development, a 12- or 15-ton gross load was extremely rare, and was typified as a road-roller used in construction. Today, in the industrial states in particular, there are countless combinations of motor vehicles in operation whose weight is more than twice that formerly assumed as the typical heavy vehicle. Quite generally the number and size of tires and the intensity of axle loads are such as to meet legal requirements set up primarily to protect the roadway pavement. In few states do the laws limit the spacing of axles in relation to gross load for the purpose of protecting the bridges. Under these circumstances the highway bridge engineer is constantly witnessing comparatively new structures being used by legal loads which exceed the safe loads for which the structure was designed. It is reasonable to encourage low-cost transportation on our roads. Heavy-duty structures—and pavements too—can no doubt be justified on our principal highways. But what constitutes a heavy-duty structure? And what are the attributes of a principal highway? In most states the bridge engineer must answer these questions for himself. The problem is not simplified by the fact that the heaviest units transported on our highways generally involve the hauling of equipment used in building or maintaining the highway itself. In the case of some highways the demands of national defense are an important consideration. It is to be hoped that legislative thought will crystallize on these matters and establish some fundamentals upon which the bridge engineer can depend. It is obviously wrong to design structures of inadequate capacity, and it seems equally unwise to expend large sums of money in overdesigning the bridges on our minor roads.

### Revamping the old bridge

Aside from the design and construction of our new bridges, is the very important problem of maintaining existing ones and making additions and betterments as needed. Years ago many stated that the roadbed and structures were permanent improvements. Facts too frequently have disproved these assumptions. The preservation of our bridge investment demands maintenance in a varying degree. The only way to determine this for each structure is to make competent periodic inspections, supplemented by special inspections as needed. For good inspection no better time can be found than during, or immediately following, a protracted "wet spell." The action of the water course under flood conditions can be observed at that time, and there is a much-needed opportunity for obtaining detailed data as to the seepage of water through the structure—too frequently the harbinger of impending disintegration. With full knowledge of the condition of each structure, all maintenance and repair work except that of an emergency nature can be planned in a routine manner.

The making of additions or betterments on a structure requires engineering judgment of a high order. The restoration, strengthening and widening of a bridge are generally more painstaking tasks than those involved in building a new structure—it requires a knowledge of all the "tricks of the trade." The commercial agencies in the bridge-building industry are doing much to assist in this work. Ingenuity in reducing dead load by the use of light weight, strong floors is the solution in many cases, even though the new floor itself is more expensive than the heavier one which it replaces, for every pound of dead-load reduction increases correspondingly the live-load capacity.

Field welding, conventional fabrication, reinforced Gunite and the developing of composite action between steel beam and concrete slab are some of the more usual expedients available to the structural engineer in revamping an old bridge to meet a new traffic demand.

Another traffic service which all state, county and city bridge engineers may be expected to give is ready information as to the capacities of structures on any given route. This is available in the Ohio Highway Department (see *Engineering News-Record*, May 17, 1934) for the state system of highways, and has met a great demand. Such a record is of inestimable value in considering permits for transporting heavy loads and planning new construction and maintenance work.

In a general discussion many important phases of bridge work cannot be touched. Time and space have restricted these comments to some of the high spots only. It is apparent, however, that the bridges are a very important part of our highway system and present a challenge to those who are responsible for their design, construction and preservation, in order that they may adequately serve the traffic of tomorrow and add to the general wealth and culture of our country.

# 6 . . . Roadside Design

### *M. W. Torkelson*

THE GREATEST COST ITEM in a construction project on a major highway is generally the pavement • Consequently most discussion has revolved around details of pavements • Yet, in a major highway, pavements are by no means first in importance • The character of the grading is much more important than the pavement, however costly the pavement may be • However important the grading, it is secondary to location and right-of-way on which road is built.

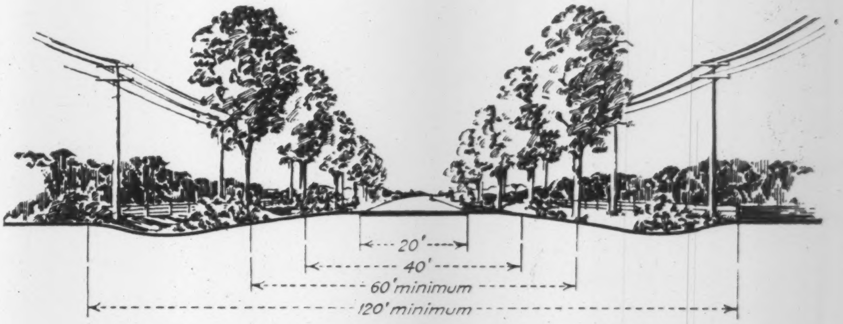
TWENTY-FIVE years ago, when we began to build roads, acting under the impression that our efforts would be an improvement on the work of the pathmaster, our view was directed backward at the horse and buggy. We had with us even then a wealth of experience indicating the limitless possibilities of inventions, those finest fruits of the human mind. Every major invention emerged in primitive form and underwent a development which realized its full possibilities. We knew that, but failed to realize the possibilities of the motor vehicle. The 25 years that have elapsed since, which include modern highway development in the United States, have been more fruitful in progress than the previous century, yet the highway engineering profession has still to free itself from the influence of the horse-and-buggy tradition.

## Plan room to grow

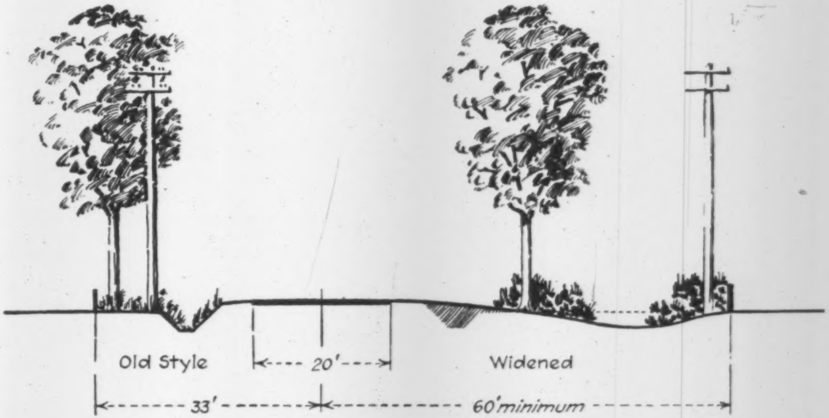
If our modern motor vehicles are better than the standard-bred drivers of 25 years ago, it is because they have more power, speed and endurance. And so the vehicles of the future will be superior to what we have today because they will have more power, speed and endurance. We need roads on which their possibilities may be realized. The ideal is a road that is straight and level, without such obstacles as grade-crossings, having a non-skid pavement of sufficient capacity and supporting power, and planned and built with proper regard to esthetic considerations. The approach to this ideal that is practicable depends on the available financial resources; the approach that is reasonable depends on the present and probable future traffic. The great care of the highway planner should be to meet the needs of the traffic that is present, or may reasonably be anticipated, with a design that may be adjusted to the developments that cannot now be foreseen. Such a design must be planned so as to be built without too great a demand on present resources and adjusted to future needs without too much scrapping of improvements existing at the time of expansion. The designer can do this best by planning and acquiring, as need and opportunity present themselves, a right-of-way that is really and truly adequate.

## Fixing the location

There are some things about highways that cannot easily be changed. One



**A ROAD DESIGN** that is capable of expansion and practicable in level or gently rolling country.



**SUGGESTIONS FOR WIDENING** existing paved road without sacrificing existing growth; practicable in level or gently rolling country. Impracticable without acquisition of new right-of-way.

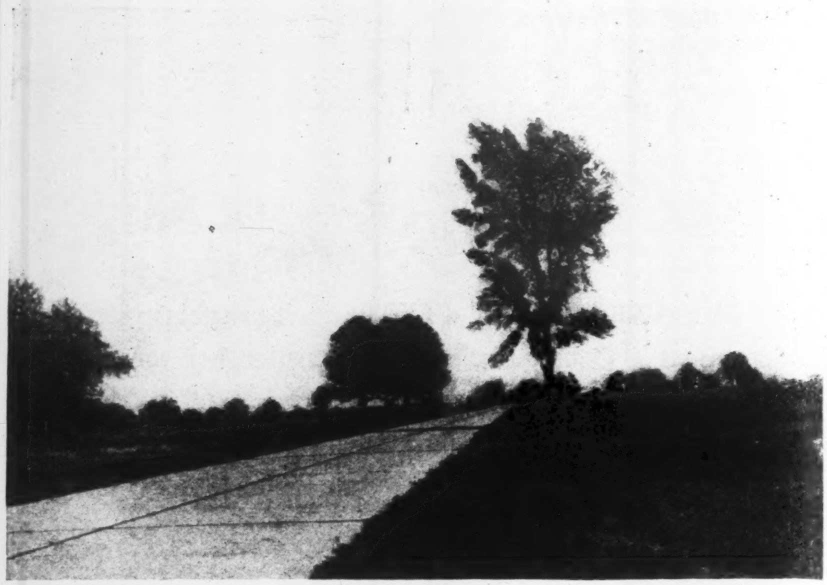
of these is the location. When we began building highways we were limited, by the same old horse and buggy incubus, to minor relocations of existing paths. As growth has taken place, we have sometimes relocated the relocations and occasionally more than once. This is expensive. To the taxpayer the abandoned locations are visible evidence that we did not know our business then; he opines that we probably are not much wiser now—scarcely to be trusted with his money.

We need to have our major highways in the right locations, not only as to general direction and termini, but in detail. Our major highways, as we now locate them, will be the tracks over which the commerce of centuries will pass. The locations which we now choose will determine the distance which that commerce must travel and the grades which it must negotiate. If the right of way is adequate, the road can readily be developed to meet the needs of future traffic; if not adequate, more right of way will have to be acquired and generally at great expense. Every major highway improvement is followed by roadside development. Country stores, roadhouses, gasoline filling stations, and other enterprises swiftly follow the pavement. Every one of these is expensive to buy out if the right-of-way has to be widened after once being paved. They crowd in toward the pavement as closely as possible. It is important to keep them out far enough so that they will not be a menace, either individually or because of vehicles which may congregate about them.

### Indispensable qualifications

The indispensable qualities which every highway must possess, if it shall not fail to fulfill the essential requirements, are three in number. Since these are equal in importance, they are named in the historical order of their appreciation. These qualities are utility—safety—beauty. The extent to which money may be expended to realize them depends on the importance of the individual road. In a major highway they must be present to a high degree. Not only are they of equal importance but they are so closely associated that each is realized to the highest degree only when the other two are present. In the proper construction of a highway, so as to provide all three qualities, an adequate right-of-way is indispensable. Let us consider the road from each of these aspects, as it influences highway design and the effect on highway right-of-way.

Modern highway traffic may be classified from the standpoint of the load carried, as either passenger or freight. Passengers are carried by privately-owned automobiles and commercial buses. In either case, these vehicles demand a road on which they can make speed. Any ordinary grades do not greatly affect a modern automobile; a six per cent grade a mile long scarcely shows them up. But they do require good alignment and adequate sight distance over summits. Without these qualities, the perfection of the modern automobile will avail little. The freight vehicle in addition demands low grades. Its success from the financial standpoint demands carrying the maximum pay load, with the result that the loads hauled are so great, in many cases, that the best speeds maintainable up the biggest hills sometimes are as slow as five miles per hour. This is not so bad for the truck, but it is bad for the automobiles that gather behind the truck. A situation is created that is fraught with danger. Perhaps the best way to ease the trouble in particular cases is to build a third or fourth lane of pavement the length of the hill in order to make it safer for the overtaking vehicle to pass, which it will attempt in spite of laws to the contrary. To carry out such pavement widening demands additional right-of-way.



**DESIGNED AND BUILT to preserve roadside growth. The land abutting is available for expansion. The growing crops are an appropriate roadside improvement.**

### Modern roadway profile

The greatest demand for new right of way, however, is caused by the type of grading which has become the orthodox practice in the last few years. One of its essential features is shoulders of a width sufficient and so surfaced that slow-moving traffic—farm wagons, traction engines, and the like—may travel on the shoulders where it will neither menace nor be menaced by the rapid motor-driven traffic traveling on the pavement.

Another essential point is a very flat slope from the shoulder to the ditch, in some cases as flat as one on six. The ditches are wide and shallow; they can scarcely be called ditches since they can be traveled in an emergency. The backslopes also are gently sloping. The purpose of such grading is in the interest of safety in that the wide graveled shoulders remove the menace of slow traffic from the pavement. When the pavements are scarcely drivable because of ice, the shoulders are much less slippery for any traffic that chooses to use them. The same shoulders, the gentle slopes into the ditches, and the wide shallow ditches give the driver of an automobile a "break" if he is so unfortunate as to misjudge his speed and leave the pavement, or if he meets a driver who insists on taking his half of the road in the center or on the left. It is an aid to the pedestrian. But it also serves a useful purpose, as it increases the confidence of the timid driver in his ability to stay out of the ditch.

Such grading is very favorable to the growth of grass and other vegetation which checks erosion. It also is well suited to the use of machinery in trimming up the roadside. Not the least of the utilitarian benefits of such grading is through a decrease in maintenance costs through machine trimming and diminished erosion. Such grading takes a wider right-of-way, but the benefits are well worth the cost.

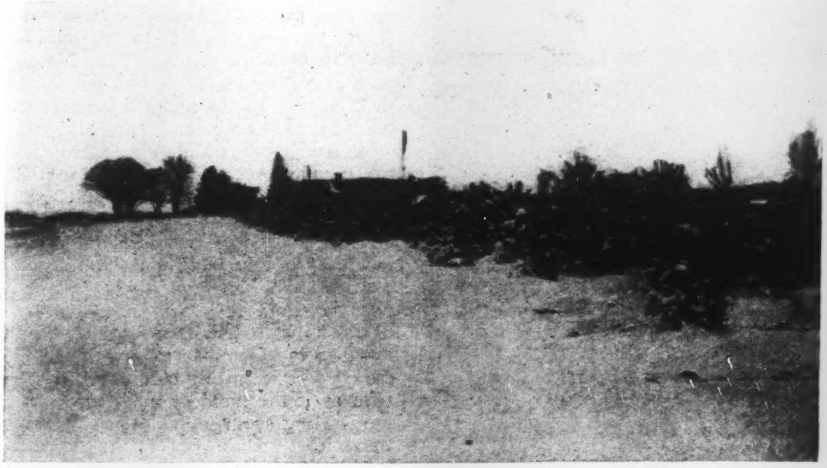
### Esthetics are fundamental

The esthetic aspect of highway construction has barely been mentioned in this discussion. It is just beginning to receive consideration among highway officials, but it appears that there will be compensation for the neglect from which it has been suffering to date. Early federal-aid laws were in advance of their time in that they specifically authorized the expenditure of federal-aid money for roadside improvement. Later enactments continue to lead in that they require that a portion of the money provided through federal grants be spent for roadside improvement under the supervision of a landscape architect. But they remain far behind the times in one respect, namely, that none of the federal-aid money may be expended for right-of-way. The earliest federal-aid legislation contained certain provisions limiting federal aid to certain amounts, so that on certain projects where costs were necessarily high, the U. S. Bureau of Public Roads did not pay the full 50 per cent of the cost. This tempted the states to cut costs even though construction might suffer. These provisions have been repealed as being not in the best public interest. The provisions prohibiting the use of federal-aid money for right-of-way purchases should likewise be repealed, and for the same reason. The cost of necessary right-of-way is as truly a part of the construction cost as is the paving and should be paid for out of the same fund.

The state highway engineers are encouraged to give great weight to the relatively superficial detail of landscaping, but are discouraged from doing adequately what is really fundamental in roadside improvement, namely, acquiring the necessary right-of-way. For it is axiomatic that roadside improvement does not mean more ornamentation of the premises within the right-of-way lines, however artistically it may be done. Such ornamentation may, in fact, be out of tune. While formal planting has its place in roadside improvement, it is out of place along a rural roadside generally; as much so as formal evening attire would be as garb for the transaction of ordinary business. Too few people realize that the problem of roadside improvement is nothing less than the preservation of the landscape, as far as it is revealed by human vision, either in its natural state, or in a state of proper and beneficial use consistent with social purposes, and its restoration to such state or use in cases where an eyesore has come into being. Too few people realize that most natural landscapes are beautiful; if they fail it is because of something man has done to mar them. Too few highway engineers realize that most, if not all, of the eyesores within the right-of-way come into being through the construction of the highway and might be avoided by proper design and construction. Roadside gravel pits with debris scattered helter skelter, steep raw backslopes, deep roadside ditches continually eroding deeper, are exhibits everywhere in evidence. Nature strives to heal these wounds; where conditions permit, vegetation in the form of volunteer growths will strive to come in, check erosion, and sometimes provide a natural planting as good as a landscape architect can plan, all at no cost. But because of inadequate right-of-way, the operations incidental to the maintenance of the road and its expansion where needed are such that the roadside is rarely left in peace, with its natural vegetation allowed to grow and develop unmolested. A too narrow right-of-way is to a road as a straightjacket to the human body. The struggles to relieve pressure at one point increase the pain at another.

An instance of what happens and is bound to happen so long as highway right-of-way is inadequate is what occurred in Wisconsin under C.W.A. in November of 1933. It is doubtless typical of what happened all over the United States. When it became necessary to find some kind of task on which men might be worked in order that they might claim the wages that would enable them to eat, large numbers were put to work on the roads at "brush cutting" and "shoulder widening." The roads, almost without exception, were built on 66-ft. right-of-way, and there was no money to buy additional right-of-way. The "brush cutting" resulted in the useless destruction of much growth that would have become a real asset to the road had it been allowed to remain a few years. The "shoulder widening" resulted in moving the ditch just a little farther out, not far enough so that the shoulder became really safe, with the same steep slopes as before, or steeper, and with many roadside trees left perched on the bank with all the roots on the roadside cut off. Perhaps they will live, but they surely will suffer. These jobs are not complete; the work will have to be done again, and because the right-of-way was inadequate. Had the right-of-way been of the necessary and proper width, a valuable and permanent improvement could have been made with the same effort.

**A PLANTED SNOW FENCE on highway right-of-way is effective, economical and beautiful.**



## Expansion requirements

Although the statement involves repetition, a major highway, considered from the standpoint of construction, must be conceived as a structure, built in such a way as to meet present needs adequately, yet without extravagance, while being capable of expansion as unforeseeable future needs may demand. Our present construction should be so designed that additional capacity, whether to meet increased volume of traffic or heavier loads, can be provided simply by adding more width or thickness to the earlier structures. Alignment and grades should closely approach perfection. All plantings between the roadbed and the right-of-way line should be out far enough so that they will not need to be disturbed. Plantings we may make today will need fifty years to attain their full beauty. It will be a pity if our lack of foresight forces their destruction because the road must be expanded. Underground public utilities can be under the shoulder slope. Telephone poles and the like should be outside of the plantings where they will not interfere and where their gaunt outlines, stark against the sky, will be subdued, hidden by trees, if such construction is still on earth when the trees arrive at such heights. In the North, where snow is a problem, we should rely on living windbreaks to cope with the drifts, preferably natural growth, but use planted windbreaks where necessary.

Such design takes right-of-way, but to paraphrase the advertisement, though it costs more, it's worth it. The first road designed on these principles to be built in Wisconsin was graded in 1931 and paved in 1932. The roadbed is 40 ft. for a 20-ft. pavement width, the slopes on shallow fills are one on six, and the backslopes are so flat they will grass up naturally. There is no guard fence. There is no reason why any should get off the embankment, and if such misfortune should occur, the driver will need only to pull back on the road. The general traveling public which, after all, is the final arbiter, has no words except praise. The cost? Rather careful estimates of the cost of the previous standard 30-ft. roadbed with the then-prevail-

RECREATION AREA OF 238 ACRES improved with parking places, picnic spots and a well with pure water.

ing slopes show an excess not exceeding $3,000 per mile. But the road is finished. Such results could not be achieved everywhere, of course. In this case much of the road was on new location, the principal right-of-way cost coming from the taking; so that the extra width did not cut much figure. But two rods of extra width on each side of the road amount to only $3,200 per mile at $400 per acre. This amount, in addition to the usual Middle-Western four rods, makes all the difference between a road that may be considered complete and one that falls short. Some judgment must be used in buying. There is generally no sense in taking the farmer's front yard or moving his buildings just in order to have the same width all the way. Buy plenty of land through the open fields, use a special section at the buildings, and leave the farmer in possession. His front yard is probably an ornament to the roadside, even though not planted at public expense. The buildings may burn down sometime, and then is the time to straighten out the right-of-way boundaries. It can be done, especially if a setback line has been established.

The principle of zoning has had its principal application in cities. Of late there have been some applications to rural districts. In Wisconsin, two classes of counties have enacted comprehensive zoning ordinances, one being Milwaukee County, the most intensively urbanized county in the state. The other class includes fifteen counties in the northern part of the state, all having sparse population and great areas of unoccupied land. The purpose of the zoning ordinances in these counties has been to head off mounting costs for roads and schools which result from isolated settlers attempting to make farms out of land that is not suitable for farming. Although these ordinances were not enacted with such a purpose, their effect is to control roadside development in the restricted districts. Forestry can be practiced, and in some cases the land may be devoted to recreation, but no commercial enterprises may be undertaken. The roadsides in the restricted districts are left in a situation that is just as desirable from the public standpoint as if they were publicly owned.

The application of this principle to ordinary agricultural territory has not been attempted in this country, so far as the writer knows, except perhaps on a limited scale in California. But the comprehensive regulation of land use is needed, and perhaps the time will come when an enlightened public intelligence will demand it. That a man may hold a fee title to certain acres for a few fleeting years is no reason why he should be permitted to destroy them for future usefulness, to the detriment of future generations. The courts are progressing faster in this respect than the general public.

Perhaps it may be thought that to attempt a development of recreation on and along the highways is wandering far afield, but such is being attempted in several states, and it is a development that cannot go too far. Our acquirements in Wisconsin on the part of the state are still limited to three in number, having areas of 238 acres, 125 acres and 40 acres respectively. They are beautiful spots abutting on state trunk highways, where the traveler may stop and rest if he wishes, amid pleasant surroundings. The purchase of the first tract was through a joint arrangement with a reluctant conservation commission. Of late the same conservation commission has changed its views and now favors carrying out this plan on a large scale. A survey is in progress to ascertain the areas that may be available for such purposes. No means of acquiring any of them is now in sight, but one never can tell what will happen. Truly, the world do move. Public opinion is educating itself to an appreciation of things it would not have understood a few years ago.

Let us hope that the time will come, and the hope does not seem impossible, when an enlightened public opinion will demand that the land along the highways without the right of way boundaries as well as within will be so managed as to be unmarred and present to the traveler a smiling landscape, as beautiful as if the hand of man, too often a devastating scourge, had never been laid upon it.

A FARMER'S FRONT YARD. A roadside "beautified" at no public expense, inspired by an improved road.

# 7 . . . Secondary Roads

### *B. E. Gray*

THAT STATE, COUNTY AND TOWNSHIP ROADS are integral parts of one road system to be jointly financed and improved, each type in proportion to its traffic and social service possibilities, is a growing conviction among authorities on highway development • The recent years have developed encouraging progress in such system coordination • In this discussion complete administrating and engineering coordination is outlined as the main consideration in the future expansion of the secondary-road system.

UNTIL RECENTLY there had been little attempt to develop a balanced program other than on a part of the nation's highway mileage. This part was the so-called primary system designated as state highways, and although it did include most of the important through roads, it also left others out, while at the same time it included some roads which were of secondary importance. The selection generally, however, was quite well made, especially when one considers the rapidity with which states were organized after the Federal Aid Act of 1916. The error of subsequent construction procedure lay in the rather universal plan to improve this mileage to a superlative degree, expending thereon all taxes obtained from motor-vehicle operation, and year by year increasing the gasoline taxes in the endeavor to reach that goal. Even federal aid was concentrated on this small mileage, leaving the other roads to be cared for by the hit-or-miss revenues from local property taxation.

What is required for the future is a rational approach to the whole problem of motor-vehicle operation in its relation to the city, the village and the farm, and a consideration of roads as an entity rather than as several competitive systems. That such an approach is becoming better understood is indicated by the fact that already five states have placed all roads under the single state authority, while a number of others extend aid in the improvement of the less important highways. To be sure, some of the impetus back of this change in authority has been the economic condition of the county and township units, yet primarily it has been due to the realization that every part of the road system is important and that coordinated control is more likely to insure a proper distribution of road benefits.

The question then is: What is a primary road, a secondary road? At best the division is a more or less arbitrary one based upon the amount and kind of traffic, and modified by the practical consideration of maintaining certain through routes to a somewhat higher standard for the kind of traffic than might be warranted by the volume. Grouping roads into state roads, county roads and township roads may not recognize this distinction, as in fact one state road may be of secondary importance and a county road may carry the heaviest kind of traffic. Whether or not it is desirable to have all highways under a single control to overcome this difficulty is a question, but regardless of the political authority it is of the greatest importance that there shall be coordinated action so that improvement and maintenance shall proceed in a logical and economical manner.

While there have been striking changes in the character of motor vehicles, in general they have been favorable to less expensive road construction, as pneumatic tires, balanced motor and body design, low center of gravity, improved suspension and springing, etc. Also, by reason of the relative costs of various types of surfacing in their ability to support traffic, there has developed a relationship between costs and traffic earnings, the latter being measured in terms of the average gas-tax and motor-registration fee received per mile of travel. Recent studies in vehicle-operating costs show quite conclusively that selection of type in accordance with traffic volume is fundamentally sound. Somewhere around 1,500 vehicles per day are required to justify a high-type pavement, with all lesser volumes being adequately cared for by the so-called low-cost types. In many locations these types will carry any traffic, and in any case are adequate for commercial vehicles of 3½ tons or less, which includes nearly all farmers' trucks and school buses.

## Traffic and mileages

Thus the only proper classification of roads is on the basis of traffic, and the first need is to make an accurate survey of road use to determine the amount and kind of traffic. Here is found a woeful lack of knowledge, and with only one or two exceptions, the record of traffic movement is extremely limited. Some records exist for state roads in some states, but as to county and township roads in most instances traffic volume is pure guesswork.

The best study of traffic flow, and the only one which includes county and township roads with any completeness, was made in Michigan in 1932 by the U. S. Bureau of Public Roads and the state highway department, and the results should be studied carefully. The survey shows traffic flow as follows:

| Class | % Total Mileage | Aver. Daily Traffic |
|---|---|---|
| State roads. . . . . . . . . . . . . . . | 9 | 1,144 |
| County roads. . . . . . . . . . . | 20 | 190 |
| Township roads. . . . . . . . . | 71 | 22 |

As a number of the state roads have traffic running to several thousands, it is clear that a substantial mileage has traffic of less than 1,000, while the county figures show that practically all the group have traffic under 500 vehicles daily. The maximum count for township roads was 279, the average 22, while only 30 per cent carried over 30 vehicles daily. The drop from the state-road group to the others is so marked that calling the first group primary roads and the others secondary is clearly correct.

It is estimated that in the United States as a whole there are about 3,000,000 miles of roads. Of this total about 330,000 are in the state system, an actual measured mileage. Using the Michigan road proportion of 20 per cent, there then would be 600,000 miles of county roads, while the remaining 2,070,000 miles would be township or district roads. It is to be borne in mind that these figures for county and township roads are estimates only, and very liberal estimates at that. They include every lane, logging road and trail that ever was set apart as a public way, and in some instances also a considerable imaginary mileage, especially where state aid was received on a proportional allotment based on mileage. In several states where all roads are now under one control, the very first speedometer measurements indicated that at least 10 per cent of the supposed mileage was non-existent or else had long since been abandoned. Therefore it is reasonable to revise these county and township figures to 540,000 and 1,860,000 miles respectively.

### Warranted expenditures

The writer presented a detailed picture of the earnings and justifiable expenditures per mile in the May 11, 1933, issue of *Engineering News-Record*, and so will not repeat them here. However, in view of the investment already made in the state system, current earnings should be sufficient to provide for all future construction and maintenance without further bond issues, and in addition provide a balance to accelerate construction on the secondary roads.

The average earnings on county roads, while materially lower than on the state system, are still of substantial amount. Again, the improvement already made on parts of the county system should permit of so allotting revenues as to bring up the general average of usefulness quite rapidly without borrowing. In fact, in many states new construction on the primary system may well be deferred, spending a large part of the revenues therefrom, over and above adequate maintenance, on the early improvement of the principal county routes, on the ground that a certain degree of further improvement will place these roads in such condition as will actually reduce present maintenance costs. For example, surface treatments to prevent the loss of road metal where replacement costs are high, and better drainage to improve subgrade stability and preserve existing surfaces now on the borderline of failure may be wise expenditures.

### Township roads

The average daily traffic on township roads is 22 vehicles, but this needs to be analyzed further in making any plans for improvement. A few such roads in Michigan had as high as 279 vehicles daily. In New England there would be some township roads with traffic running into the thousands. They should receive improvement as required by the needs of such traffic, and under a proper reclassification would be included in the state and county brackets. At most, however, they would hardly total 10,000 miles and when some of the low-traffic roads in the county group are also reclassified, the effect on total percentage will be small.

### Central administration advantageous

It is hard to see how this township group can be financed by its own earnings. However, the value of those roads from the standpoint of land service and the preservation of minimum social standards undoubtedly warrant their further improvement, and unless the earnings of the more important roads provide a balance applicable to them, direct local property taxation must be levied for this purpose. On one point there can be no doubt, by revising methods of control, that a much higher grade of service can be afforded by these roads with no greater expenditure than is now being made. By the very nature of things, town or district authorities as a rule are neither properly equipped nor in command of the necessary technical knowledge. No matter how honest the effort, pick and shovel cannot achieve the same results as a heavy tractor-grader, when the latter has enough work to keep it continually in use.

The experience in North Carolina and Virginia indicates that with an average of $100 per mile per year, this class of roads can be not only maintained but also steadily improved and over a period of years may be definitely raised to a condition of satisfactory traffic support. Some roads may receive as little as $25 per mile, and others several hundred dollars, according to the immediate need and amount of traffic. Few roads are consistently bad; it is the 50 or 100 ft. here and there which make the whole road impassable. When drained and graded and occasionally on short sections surfaced with selected local material, they are surprisingly good for the greater part of the year.

### Financing possibilities

With this picture of traffic conditions and service it may be of interest to see what the program would be if all work were coordinated, the state and county roads receiving money in proportion to annual earnings, and the township group receiving $100 per mile. As a better definition the groups will be called Classes A, B and C as in the accompanying table.

The present income from gas tax, registration fees and federal aid is sufficient to cover Class A and B mileages and a part of Class C, provided these revenues are not diverted. It is to be remembered that federal aid has been covered by the 1c. gas tax and the special taxes on motor vehicles. As previously outlined, there undoubtedly can be some shift of funds from the Class A group to the Class B and C groups, at least for a few years until a better balance is obtained between all roads. This total sum of $1,286,000,000 annually is somewhat less than the average of the past few years, but in light of present knowledge it can be made sufficient; first because such a substantial percentage of the heavy traffic mileage has been improved, and second because fewer roads will receive expenditures beyond their need.

Some may question this statement of serious overbuilding and be afraid that a business revival will bring such a flood of traffic as will pound roads to pieces. It is believed that the unique experience of the twenties still colors their views, and that a full realization of the change in low-cost road technique is not developed. After four years of declining car registration it should be realized that future expansion will be at a slower pace and in accord with population growth. If 26,000,000 cars were able to travel the road net of four years ago and since from current expenditures not only are roads being maintained in status quo but are being very definitely improved, it would seem that not much fear need be exercised in this regard. It is a completely safe plan to proceed on the theory that the picture gained after a complete traffic survey is relatively the picture that will be continued in the future. If present traffic is 200 vehicles per day, it may increase to 400 vehicles a day after improvement, but a surface built for this volume of traffic can be further improved under maintenance and within the revenue from the additional traffic as it is received.

### Examples of secondary systems

One of the first states to develop a secondary system was Massachusetts in the early 1900's before ideas had grown concerning the superlative character of a state highway system as compared with a township system, and from this early date annual allotments were made from the state fund to aid the towns in constructing certain highways. These

MILEAGE, TRAFFIC AND PROPORTIONATE ALLOCATION OF FUNDS FOR THREE CLASSES OF ROADS

| Classification | Mileage | Average Daily Traffic | Allocation of Funds |
|---|---|---|---|
| Primary group | 330,000 | 1,174 | $550,000,000 |
| Class A (state roads) | 12 per cent | | |
| Secondary group | 540,000 | 190 | 350,000,000 |
| Class B (county) | 20 per cent | | |
| Class C | 1,860 000 | 22 | 186,000,000 |
| (town or district) | 68 per cent | | |
| Total | | | $1,086,000,000 |
| Special federal appropriation | | | $200,000,000 |
| Grand Total | | | $1,286,000,000 |

highways were selected jointly by the state and the town, and simultaneously these annual increments of improved highways were constructed, until after some ten or fifteen years they began to connect with one another even though the annual expenditures in many instances were less than $1,000 per town per year. The cross-section was usually 18 to 20 ft. between ditches with a gravel surface 15 ft. wide. Considerable attention was given to setting an accurate grade line for both surfacing and ditches; culverts were installed where required, and pains were taken in placing gravel surfaces.

As the years went by, the usual maintenance of cleaning ditches, cutting back curves, superelevating curves, and other betterment operations, resulted in obtaining a roadway width of aproximately 24 ft., with the gravel surface still maintained at 15 ft. These roads before connection were carrying a light to medium traffic only, rarely as much as 500 vehicles a day. Beginning about 1920 surface treatments were being placed and have been continued since on many of these roads. Because of a dense population and the large number of cities, there is a tremendous volume of week-end and holiday traffic, and this net of township roads built over the years and often unchanged as to width or kind of surface carries this increased load at moderate cost. The state highway system is less than 2,000 miles, but the secondary system of excellent stone or gravel surfaces totals some 15,000 miles and affords a distribution of traffic in such a way as to reduce crowding on the state system, furnish enjoyable avenues for pleasure driving, and give year-round service to the rural communities located thereon.

For low-volume traffic, a much lesser width of surface will adequately serve as compared with volume in the thousands. To be sure, a 10-ft. lane is desirable, but it is a demonstrated fact that a 14- to 16-ft. width on a winding alignment is adequate for light to medium traffic and gives fewer accidents than occur on the wider lanes where high speeds and crowding exist.

Another state with a splendid secondary road system is Pennsylvania, and it has been largely built during a very short period. In the past four years some 12,000 miles have been constructed. The old roadbed has been followed closely to reduce the cost of grading, and to utilize stabilized subgrades and existing drainage structures wherever possible. A minimum width between ditches of 22 ft. has been obtained, and the surfacing is a minimum of 14 ft. Local materials have been used wherever possible, but very solid bases of not less than 8-in. depth have been generally constructed. Necessary drainage structures have been installed, and the finished surface usually receives a bituminous treatment. The average cost per mile has been about $6,000, including grading, drainage and surfacing, and the results are excellent. It is not possible to appreciate the great improvement in traffic movement, social betterments, and relief to the crowded primary system, until an actual inspection is made. The salesman visits the village stores more frequently and sells more goods, while the farmer and village resident have free access at all times to outside markets for their products.

## Simple engineering technique

A different technique in engineering procedure is required for secondary roads than for primary roads on account of cost. Unless the state law requires a lot of records for right-of-way, the surveys can be made very simply. In general the alignment and grade are determined within close limits at the time of the survey. The chief of party determines the control points, taking every advantage of the ground within the old road limits so as to flatten curves and improve sight distance, but not necessarily to obtain longer tangents. This is especially true in hilly or mountainous country. The main idea is to obtain a uniform condition of grade and alignment, and 20 deg. curves or 9 per cent grades are not objectionable provided they fit the country. The line even may be run in by eye, and some spirals have been run on many miles by this method upon which it would be hard to improve.

Stakes should be set opposite each 50-ft. station at the time of the original survey, and well outside the probable construction limits as they will serve later as grade stakes. Cross-sections are taken at the 50- and 100-ft. stations, and at intermediate points only when some unusual break occurs. Topography is taken only of features that bear upon construction, such as buildings, fences, utility structures and unusual trees. Benchmarks are established and referenced at 1,000-ft. intervals, and sometimes the line is referenced if right-of-way descriptions are to be recorded. It is astonishing how rapidly such surveys can proceed. The writer was a member of a three-man party years ago which regularly ran out a half mile of line, drove and marked the grade stakes, took cross-sections and topography and rechecked the level line, all in eight hours, and in hilly country with one curve after another and frequent turning points.

In the office the profile and cross-sections are plotted, a grade line is set, and quantities are figured for the purpose of balancing cut and fill. The grade should follow the old road as closely as possible, to utilize the consolidated roadbed unless a fill section is required to improve drainage. A stake sheet and culvert sheet are made up, and with a 50-ft. metallic tape and a 6-ft. rule the resident engineer can mark the grades on the previously set stakes and proceed to construct the whole road without any more instrument work. One of the hardest things to resist is the making of useless records, but engineers should remember that the object is to build roads and not plans.

From observation of this class of work over many years, it seems that the force-account method is superior to the contract method for many of the items, such as grading, surfacing and drainage. Guard-rail and bridge work and bituminous treatment may be done equally well by contract, but in the very nature of things, greater utility of local conditions can be made when it is possible to make slight changes, as the work proceeds without a lot of new engineering, something which is very difficult to avoid on contract work. Also under force-account work it is rarely necessary to take final cross-sections, as in most cases the original stakes will be still in place and any checking of original layout is readily done. Furthermore, with a large program under way, equipment can be rotated as needed and work a greater number of days per year. Eight per cent should cover all surveys, plans and inspections as a rule. This procedure in general governs the Class B roads.

The Class C roads survey is simply a speedometer run to determine distances, and with suitable notes taken at different seasons as to road behavior. All other improvement is a matter of judgment while the work is being done, so far as any betterment of alignment and grade are concerned. The following steps are taken in the order of improving the road itself: (1) cut brush and trees close to road; (2) blade surface and establish side ditches; (3) establish flat cross-ditches until drainage structures can be built; (4) surface worst places.

It may take five years to get around to all items; but by careful planning the road will be a little better each year than the year before, and once such progress is under way the goal of a year-around surface becomes a reasonable possibility.

## Social possibilities

In all the discussion so far, emphasis has been placed upon the service to traffic. What about the service to the man who works on the road? The construction and maintenance of highways are big undertakings, but there are opportunities for stability of employment and adjustment of some farm problems that have not yet been fully utilized. Years ago roads were maintained almost entirely under the patrol system, several miles to the man. The patrolman usually had a small home on the road, and as he only worked part time he devoted his other time to raising a garden, and taking care of a few chickens, a pig, a cow and a horse.

There were many single rigs in those days. These places today would be called submarginal farms with the owner in want, but then the man raised his food and fuel, and the part-time pay for road work paid his taxes, bought his clothes, educated his family and in some cases put a little money in the bank. These men were loyal, trustworthy, and under competent direction did excellent work. The produce from the farm was consumed on the place, and never became a part of an unsaleable surplus. The family was a fine upstanding one, self-respecting and self-reliant. Where has it gone?

For one thing, the lure of higher wages drew the young people to the city, and this in turn led to the greater use of machinery and the gang system where the men were brought out from the towns and cities to work in the country. However, it would now seem an excellent time to link the submarginal farm problem with future road development. Many farms can almost pay. What is lacking is that small amount of cash to cover items which must be purchased. Thirty dollars a month cash income plus the farm produce will make most of them a paying proposition.

### A federal-aid proposal

In order to get the plan under way all over the country, let the federal government appropriate $200,000,000 yearly for secondary roads, to be improved under state supervision whether or not they are under its jurisdiction. Have the work done by force account, and give first preference to resident owners or tenants on farms with an assessed valuation under $3,000, and until all such applicants wishing work have been employed, let the monthly earnings be limited to $30. Assuming the low figure of 50 per cent for local labor in this class of work, over 300,000 families would be made independent again, local taxes would be paid, land values would become firmer and a vastly improved road system with increased earning power would result. The state should handle the work as it has the organization, the equipment and the knowledge to proceed and it could get going over night.

It is believed that the full development of secondary roads is the most important program ahead in roadbuilding, and that more miles of year-round roads that will uniformly distribute traffic are required rather than the ultra-refinement of a few miles of highly improved road.

# 8 . . . Highway Safety

## *E. W. James*

Highway intersection safeguards • Separated roadways • Provisions for walking and parking • Clearance for loss of vehicle control • The superhighway • Use of signs and signals • The driver and the vehicle • All are essential parts of the safe highway.

WHEN the motor vehicle first created a need for new standards of highway design, the highway engineer was concerned primarily with the development of smoother and more durable road surfaces, and as the number of vehicles increased, with the creation of enlarged highway facilities for greater capacity. Safety, it was believed, would be the natural consequence of smoother, wider and straighter highways. It seemed coincidental that the same improvements which satisfied the demands for greater ease and speed of travel also made that travel safer.

But the problem has not proved so simple. It was not foreseen that the very improvements which should make for safety would also permit and encourage an even more rapid development of high-speed motor vehicles. Accidents still continue to happen in spite of everything we have done. Preliminary estimates of motor-vehicle fatalities for 1934 indicate a probable increase of at least 15 per cent over 1933. It is not sufficient to blame these deaths on misuse of the roads by a relatively small part of the driving public, though such misuse is unquestionably a major factor in the accident problem.

There is no indication that the limit in motor-vehicle speeds has been or will soon be reached. Furthermore, despite a depression decline in registrations since 1930, the "saturation point" in motor-vehicle ownership has not been reached. Especially may we look for an increased development of freight transportation by motor truck. The highway engineer must accept these facts and, within limits set by the funds at his disposal, he must not only design and construct highways sufficiently spacious to accommodate present traffic and its normal future increase without undue traffic delay, but he must also safeguard them against every hazard that high-powered, high-speed motor vehicles can create in the hands of inattentive, negligent, incompetent or reckless drivers.

### General principles

In its simplest terms, the prevention of highway accidents is the prevention of collisions between motor vehicles and other vehicles, pedestrians or stationary objects. A collision requires the presence of two bodies seeking to occupy the same space at the same time. The objective of the highway engineer must be to keep these bodies separated in space or in time. As long as vehicles moving at different speeds must use the same highway lanes, it is not possible to maintain this separation positively at all times. Separate roadway surfaces can be provided for vehicles moving in different directions, however, or, where this is for the time being impracticable, separation in time may be achieved by means of traffic signals or other type of traffic control.

The following discussion will consider the means by which these principles may be applied.

### Intersection safeguards

The principal source of conflict between vehicle movements lies in intersections. At an ordinary cross-road there are twelve possible courses for vehicles to follow. Each, except the right turns, cuts across four other possible paths. Occasional collisions under such circumstances are inevitable, es-

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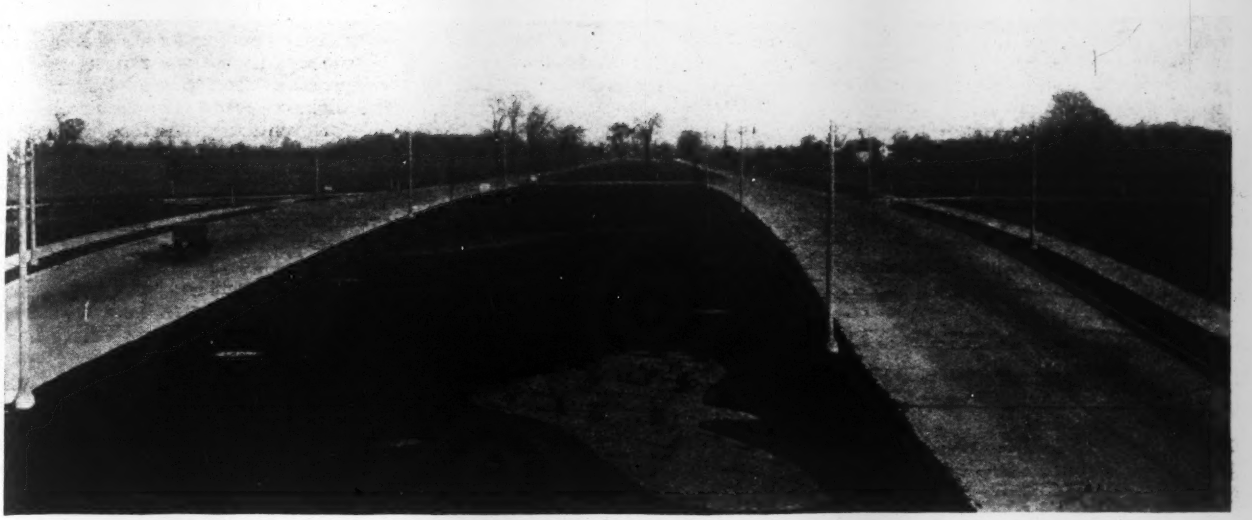


**A DIVIDED HIGHWAY with a lesser highway intersecting at grade; pedestrian footpaths shown at the outer edges of the pavements.**

pecially at the high speeds of rural travel. The remedy must be found either in a redesigning of the intersection or in setting up some form of traffic control. A traffic signal denies to any vehicle the right to use any portion of the roadway desired by another vehicle moving in a different direction, except when one of them is turning to the left. A stop sign on one of the roads accomplishes a similar purpose, but with a less positive defining of rights. Both types of regulation have the defect that they depend on the motor-vehicle operator for a more or less conscious obedience (which obedience often suffers disastrous lapses), and neither solves the left-turn problem with its possibilities of almost head-on collisions. Wisely used, however, these devices achieve an orderly movement of vehicles and a notable reduction in hazard.

Redesign of intersections to reduce possibility of collisions calls for additional right-of-way and more elaborate construction which, because of cost or unfavorable topography, may be difficult to provide for. The "traffic circle" or modification of it, where designed with adequate radius, permits the interweaving of traffic moving in essentially parallel lanes. There is no reduction in the number of intersecting paths, but the crossings are accomplished with a minimum likelihood of serious collision. The circle also imposes on the traffic a limitation in speed through the intersection danger zone. As a multiple intersection where more than two roads cross, a traffic circle is almost the only means of securing orderly movement.

The only certain way to prevent intersection collisions is to eliminate the intersections, to separate completely the paths of vehicles moving in different directions by means of a grade-separation structure. To accommodate turning movements, ramps must connect the two roadway grades, and, if all intersecting movements are to be eliminated, a cloverleaf design with a ramp in each quadrant is necessary. When all left turns are made in spiral fashion—that is, by crossing over or under the intersecting road and then making two successive right turns—no vehicle need ever cross the path of another, and the only possibility of collision arises when a vehicle turns to the right into a through traffic lane, a minor hazard, especially on multi-laned roads. The confusion now experienced by many motorists in trying to make their turns correctly may be expected to disappear as the cloverleaf design is more commonly used.

The minor intersections of local or private roads or driveways with through highways are a constant danger because they are so numerous and, frequently, so obscure. Expensive treatment of each individually by traffic signals or redesign cannot be justified, and stop signs too often fail in their purpose because of non-observance by drivers.

Accordingly, the concept of the freeway has been developed—a highway for express traffic to which the abutting property has no right of access. All local traffic must use service roads in the vicinity, and traffic may enter or leave the freeway only at widely spaced intersections where it can be properly safeguarded. Under this plan, a new express highway remains an express highway instead of becoming just another suburban or urban street.

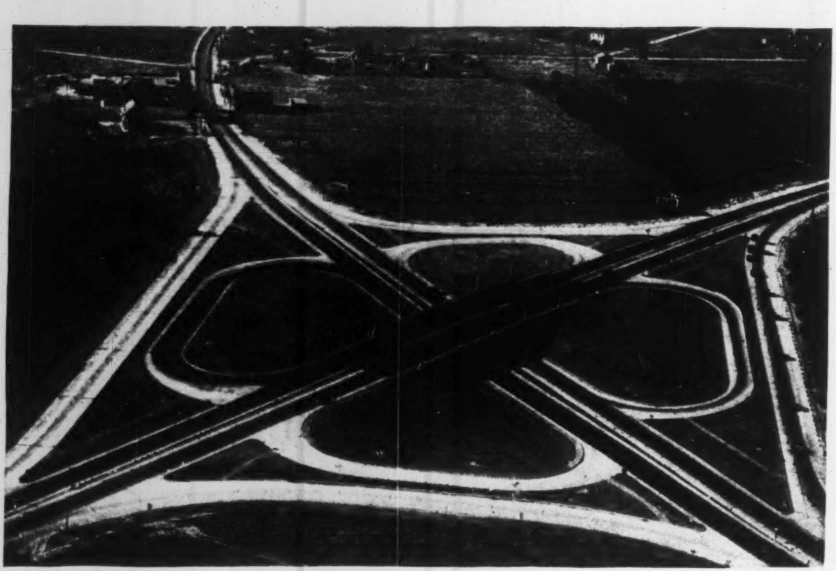
The problem of railroad-highway crossings is similar to that of highway intersections, in that only a separation of grades can make safety sure, especially with the development of the new high-speed trains. There is a growing sentiment in favor of closing many existing crossings and providing more adequate protection, or grade separation, at the others, on the theory that modern motor-vehicle traffic can well afford the slight expense and inconvenience of detouring a mile or more for the advantage of greater protection. For protection of the remaining crossings where grade separation is not practicable, the standard flashing lights of wigwag signals, put into operation by approaching trains, are becoming more general on the rural highways.

## Separated roadways

Considering the number of vehicles which pass each other in opposite directions on the open road, the statistical chance of any two colliding is infinitesimally small. In the aggregate, however, head-on collisions make up a very serious part of the total, and among the earliest of highway improvements was the widening of the pavements to increase passing clearances. Demands for greater traffic capacity have been met by widening to three lanes, four lanes and more, but vehicles using the center lane or lanes must still pass close to opposing cars and, in addition, face the added danger of being crowded by cars on their right.

The painted center line, which is now almost universal on curves and on hills, especially where sight distance is impaired, is effective and popular, but it cannot prevent the careless motorist from crossing over to the wrong side at times, with possible serious consequences. Actually, non-observance of lane marking by drivers is common. The expedient has also been tried of designing the center lanes of three- or four-lane roads with a differently colored and sometimes slightly rougher surface, to differentiate them more distinctly and discourage their use except for overtaking and passing.

It is clear, however, that to keep opposing cars safely apart there must be some physical barrier between them. The safe highway must be built with two separated roadways, each for traffic in one direction only. Each roadway must be at least two lanes in width to accommodate fast and slow traffic in different lanes. Until vastly greater highway funds are available, therefore, this design will probably be limited to highways on which the volume of traffic justifies the expense of four-lane construction. A recent study in Massachusetts showed only 54 per cent as many fatal non-intersection accidents per million vehicle-miles (excluding pedestrian accidents) on divided highways as on ordinary four-lane highways, and only 37 per cent as many as on two-lane roads. An incidental but important advantage of the dividing center strip is that it may be planted to serve as a screen against opposing headlights, thus removing permanently one of the greatest hazards of night driving. At intersections where it has not been feasible to separate grades, furthermore, it offers a very desirable "dead" area between the opposing traffic streams where a crossing or turning vehicle may remain protected until a favorable opportunity occurs for entering or crossing the traffic on the far side of the roadway.



**A CLOVERLEAF INTERSECTION** showing inner spiral ramps for left turns.

## Walking and parking

Closely related to the separation of intersecting and opposing traffic is the removal of pedestrians and standing vehicles from the path of moving traffic. We have done little for the pedestrian on rural highways except to admonish him to walk on the left, facing traffic. When vehicles crowd him off the pavement he must pick his way as best he can. Safety demands that a surfaced footpath be constructed on at least one side of every highway commonly used by pedestrians.

The parked or disabled vehicle is most dangerous at night. In case of a major breakdown it may be impossible at once to remove a vehicle from the pavement and, if visibility is poor, flares or other warnings must be resorted to. As a rule, however, when a vehicle is halted by tire or engine trouble, or by the desire of its occupants to rest for a time, it stops on the pavement simply because there is no practical space for it elsewhere on the right-of-way. To keep the traveled lanes safely clear of stopped vehicles every highway must be designed with shoulders wide enough, smooth enough, and substantial enough to serve as an emergency traffic lane.

## Extra clearance

The last major type of collision occurs when vehicles, through careless operation or loss of control, crash into fixed objects outside their proper paths—poles, trees, culvert headwalls, bridge abutments, buildings, ditch banks, or slopes. These accidents are usually to be attributed to excessive speed or negligent operation, yet the highway engineer cannot escape at least partial responsibility for the consequences. Skidding, a frequent factor, can and must be held to a minimum by proper design of road surfaces. Experimental research has demonstrated the possibility of combining smooth riding qualities with a rough surface texture on which tires can hold firmly. High crowns, necessary for drainage of the more primitive types of road, are giving way to the almost flat top of modern waterproof pavements. Curves, too, are being superelevated to counteract the centrifugal skidding force. The degree of superelevation has usually been a compromise, since proper banking for the highest speeds may be uncomfortable or even dangerous for slow traffic.

For the protection of a car, once it has gone out of control, plenty of open space in which to come to a stop is the principal desideratum. Culverts should be extended through wide shoulders, and bridges should be at least as wide as the pavement and preferably wide enough to give extra lane clearance. Generous shoulders clear of obstructions and gentle ditch slopes will often make a minor accident out of what otherwise would be very serious. On embankments or side hills, guard fences of wire cable or steel ribbon offer a last chance of safety and, incidentally, are a valuable psychological aid to all drivers.

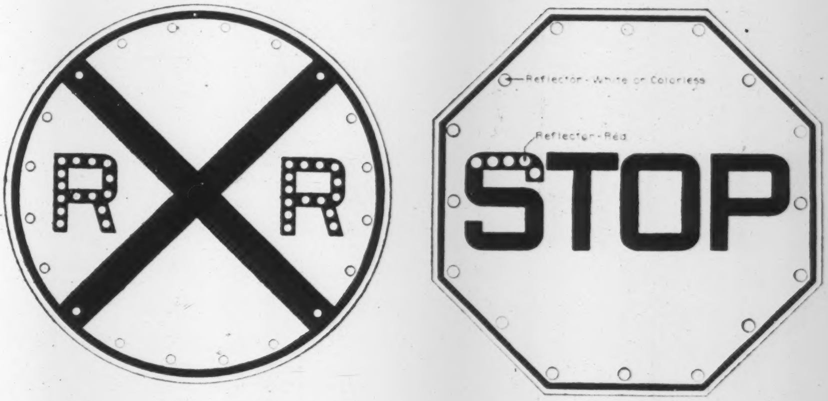
## The superhighway

In the light of the previous discussion it is possible to describe the express highway as the highway engineer would like to see it, the superhighway built for the modern motor vehicle or the vehicle of the future. Few areas can now produce enough traffic to justify the most expensive type of construction, but even the less important highways may have some of its features, and the probability of future development should always be considered in present planning.

The superhighway will be a freeway, with a divided roadway and no highway intersections or railroad crossings at grade. Connections with other highways will be widely spaced and designed, to cause the minimum of confusion or conflict. If pedestrians are given access to the right-of-way, they shall be provided with sidewalks and required to use them. Provision shall be made for the safe removal of disabled vehicles from the traveled way. On such a highway it will be possible to enforce minimum speed limits to maintain a free and efficient flow when traffic is heavy. On the other hand, our present experience would seem to indicate a need for maximum speed limits, to curb a small minority who enjoy reckless speed. Minimum hazard in one-way traffic is achieved when speeds are most nearly uniform. For the most part, however, the superhighway will depend for its safety on its physical design, which will make it difficult for the motor-vehicle operator not to do the safe thing.

## Signs and signals

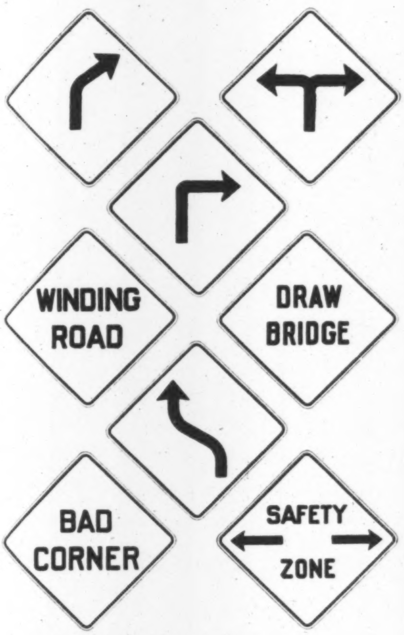
For reasons already suggested the ideal highway is and always will be a luxury, sometimes a very necessary luxury. It will be many years before any extensive mileage of through routes can be given superhighway treatment even under the most liberal public-works program. Meanwhile, we



**CIRCULAR SIGNS** indicate approach of a railway grade-crossing and octagonal signs indicate a place where a full stop is demanded

shall have to make use of our present roads and by degrees improve them in the direction of our ideal. In any case we shall continue to need local roads for general utility purposes. On all roads the hazard inherent in their physical design must be corrected by traffic regulation and control, and the judgment of the vehicle driver must be assisted by warning devices of one sort or another.

Warning devices must first be effective, and, as a corollary, they must be essentially uniform so as to be recognized by the vehicle operator wherever he happens to be. Under the auspices of the American Association of State Highway Officials and the National Conference on Street and Highway Safety, a standard series of warning signs and markers has been devised and has been almost universally adopted by the states.



**DIAMOND SIGNS** indicate places where some danger inherent in road design or plan calls for slow speed.

At present-day speeds, motorists have only a brief instant in which to see and react to highway warning signs. Wherever possible, therefore, clear and unmistakable symbols are to be preferred to even the briefest text. The nationally standard signs indicate by their outward shapes alone the general type of warning to be conveyed. No systematic publicity has been given this fact, and it is probable that few motorists are consciously aware of it. The circular sign is seen only as an advance warning of railroad grade crossings; the octagon is used only to indicate a full stop; the diamond, or lozenge-shaped sign, calls for slow speed where some danger is inherent in the road design or plan, such as a curve, a hill, or a narrow bridge; and a rectangular sign indicates that caution is necessary because of a special or intermittent hazard such as a school, loose gravel or men working. Reflecting buttons outlining the signs or their symbols are highly desirable if the signs are to be of maximum service during the hours of darkness.

The general and intelligent installation of these standard signs should be undertaken by all the states. The existence of minor differences or preferences with regard to some details should be disregarded and a frank recognition given to the fact that more uniformity has an advantage over variety in the use of such devices. As a matter of fact, the important details, such as color combinations, size and shape, and the limited use of symbols, are the result of extensive tests made by a group of interested and competent agencies over a period of about ten years. They should be adopted universally.

Traffic signals, as distinct from warning signs, are intended definitely to indicate the correct movement of vehicles regardless of the individual judgment of the vehicle operators. At heavily traveled intersections they are the only means other than personal police direction for maintaining an orderly and systematic flow. The time is divided into brief intervals, and traffic on each street alternately is given the right to move freely without interference from cross-flow. Where traffic is light or irregular, the arbitrary assignment of intervals by a fixed time signal may cause unnecessary and costly delay. Still worse, it often leads to violations by impatient drivers, a most serious condition, since each operator must assume that others are obeying the signal. This difficulty is overcome, and an almost ideal situation is attained by use of the traffic-actuated signal, which, when properly designed and regulated, gives traffic on each road precedence in order of arrival and yet keeps the intersecting movements distinct and separated in time.

Somewhat outside the field of the highway engineer, because not directly related to the design or construction of the highway, there is another phase of traffic safety that is of growing importance. This concerns itself with the qualifications of the driver and of the vehicle under his control. Increasing speeds and volumes of traffic have placed correspondingly increased responsibilities on the motor-vehicle operator. There are many who, through physical, mental or temperamental defect, are incapable of taking powerful cars out on the highways with safety to themselves or to others. It is a well-recognized fact that a limited group of vehicle operators is involved in a very disproportionately large number of accidents. The most successful control of the accident-prone driver has been through licensing laws which provide first for the testing of every applicant prior to issuance of his license, and second, for the suspension or revocation of the license of anyone who proves himself unfit to continue as a driver.

### The vehicle and safety

The condition of the vehicle, particularly as to brakes and steering gear, is just as important to safety as is the condition of the driver or of the highway. The designers and manufacturers of automobiles have produced machines that are dependable and safe, but only so long as they are given proper care. Car-inspection campaigns in many cities and states have shown that few cars are in really good mechanical condition, and that many are so badly out of repair as to be a menace to everybody on the road. Here, as in the case of the vehicle operator, it is necessary to prescribe tests for fitness, with certificates permitting operation issued only if the tests are passed successfully. These tests, of course, cannot be given frequently enough to prevent mechanical depreciation and neglect between times, but even if given only once a year they may be expected to serve a valuable educational end.

# ENGINEERING NEWS-RECORD

Volume 114, No. 3. Copyright 1935 by McGraw-Hill Publishing Company, Inc.

EDITOR—F. E. Schmitt. EDITORIAL STAFF—V. T. Boughton, N. A. Bowers, W. G. Bowman, W. W. DeBerard, F. W. Herring, C. S. Hill, H. W. Richardson, J. I. Ballard.

Editorial and Publishing Offices at 330 West 42d Street, New York

January 17, 1935

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## *Moving Toward Unity*

IN THE MEETING of the American Engineering Council last week there was apparent a new spirit of cohesion within the profession, an evident purpose to organize for joint action of the great professional body. It is a welcome spirit, one that forecasts greater effectiveness of the profession. A real expression of a broad movement of integration, it is related both to the larger unification of the construction industry that is embodied in the code group, and to the gathering of forces that is taking place in the strengthening of the Construction League as the industry's centralizing agency. Engineers, it is plain, are conscious of their twofold responsibility as members of a comprehensive industry and as a professional corpus, and recognize the need for effective organization in both fields. Their professional relation to the world is likely to find marked help from the work of the new state committees on public affairs which the Council is setting up; these organizations, if properly active, will for the first time place a coherent technical opinion before legislators. In the same sense the industrial interest of engineers is likely to be served by more intimate participation in code work and in the activities of the Construction League and its local representative groups.

## *Consolidated Mapping*

CONSOLIDATION of the mapping functions of the several federal departments is about to become effective, according to reports from Washington. Such a move has long appeared desirable to many engineers, both inside and outside of government service, but several things have stood in the way of consummation, chiefly interdepartmental jealousies and fear of loss of prerogatives. The change is particularly desirable now in view of the recommendation of the National Resources Board that the mapping of the country be pushed to completion within a period of ten years. We now have the Coast and Geodetic Survey laying down the basic network and the Geological Survey making the topographic maps, with a score of other agencies doing survey and map-making work on a much smaller scale. To centralize all this work would be a mistake and would result in needless loss of efficiency in unit operations, especially if the attempt were made to include site surveys or line and grade work in construction. For example, surveys made in connection with the construction of a dam should still be made by the agency in charge of construction; but where that agency requires a map of a large area, such as a whole watershed, the survey and map should be made by the consolidated service. Thus duplication of major survey operations will be avoided, and those who undertake such operations will have available within their own department the notes and records of all the important lines that have been run through the area to be surveyed. Information as to work done on a minor scale can clear through the consolidated service or other body, and the full coordination and information would be assured. In every respect governmental efficiency would gain.

## *A Time of Opportunity*

THE ASSOCIATED GENERAL CONTRACTORS in approaching its annual convention has before it the greatest opportunity in its sixteen years of life. Never before has the need of a united front been so vital to contracting. Having devoted the past year to launching the code, a difficult job well done, the A.G.C. can now turn to other problems. And there are problems that endanger the welfare of contracting. The first task is to sell construction. Obsolescence has created the greatest construction market in history, but this market still waits to be sold. The next is to sell contracting, which means that public confidence in the ability and integrity of contractors must be won—through championing efficiency and quality of contract performance, as well as through eliminating the incompetent contractor. Third, and not least important, is to fight high construction costs; wage scales and other perplexing matters of labor relations are here involved, as well as increasing compensation insurance costs. These are but a few of the problems that face contracting. They can be solved only by an organization large enough to gain the confidence of government, industry and the public, an organization that represents small as well as large contractors. A strong program for the betterment of contracting can build such an organization.

## *Administering the National Estate*

JUST AS ALL BUSINESS PRINCIPLE dictates that the lands and other property of individuals or corporations be managed in accordance with its characteristics and best uses, so the nation's property deserves to be managed. It has not been so managed in the past. The recommendations on land policy submitted by the land section of the National Resources Board represent the first attempt to outline a businesslike course of action. Due to past neglect, forests and minerals have been wasted, grazing lands have been depleted, good agricultural soil has been destroyed. Whole populations have been exposed to misfortune as a result of erosion, damage to water courses, irrecoverable ruin of great forests, and destruction of productive farm lands. It is timely that a purposeful effort should be made to reform this sorry condition. But the magnitude of the problem is such that results can be attained only slowly. A vast amount of further study is obviously needed before anything like a comprehensive scheme of management of the national assets can be formulated. The studies of water, land and mineral conservation made under the authority of the National Resources Board mark out the right lines for action. They should be continued.

## *Arch Trainsheds*

THE GREAT STEEL TRAINSHED of the LaSalle Street Station in Chicago is a thing of the past. It is the last of the great steel-arch trainsheds in this country that a quarter of a century ago were accepted as the acme of large passenger terminal design. Though fast disappearing in this country, large vaulted trainsheds are still being built in Europe, but they are being built of reinforced concrete to reduce, if not to eliminate, the attack of corrosion that spelled the early doom of the steel structures here. In recent years several notable reinforced-concrete arch roofs have been built in Europe for enclosures such as trainsheds, exhibition halls and hangars. This development raises the interesting question as to whether we would not still be using great halls such as that at LaSalle Street, had the art of reinforced-concrete design proceeded at a faster pace in this country or had it been characterized in its earlier days by the boldness that is so notable in European design. The more complete enclosure provided by arch-type trainsheds and the unobstructed track and platform areas that they provide constitute advantages that might still outweigh the higher first cost were maintenance and renewal burdens reduced.

## The Issue is Recovery

IN VIEW of the great promise contained in the recovery employment plan announced by the President in his opening message to Congress, the risk of failure which the plan involves should not be overlooked or regarded lightly. The chief dangers lie in two directions:

The first source of danger is the prospect that work projects will be selected not for their value or recovery effect but for the amount of direct job labor which they require. The message itself indicated that such selection would be the aim. Every engineer and construction man knows, however, that projects so chosen would be of little use for recovery; their effect would be confined to the men employed, while the army of men in mine, mill and railroad service who would be given work through wiser project selection would remain idle. Direct-labor projects and hand-labor methods are twin roads to economic chaos.

Even more serious results will follow if a huge force-account system is set up to carry out the program, as the message suggests and as reports from the President's press conferences seem to confirm. That such a system would deal a staggering blow to the construction industry is for the moment secondary; the critical fact is that recovery instead of being furthered would suffer a setback. A glorified CWA campaign—for this is what the force-account system means—would be so utterly apart from the country's normal business activity that it might as well be carried on within penitentiary walls for all the recovery influence it could exert.

Some elements of the President's program, it is true, are properly adapted to force-account operation—soil erosion and reforestation work, for example. But the project list includes also housing, highway construction, grade-crossing elimination, and non-federal work of self-liquidating character such as water supplies. What will be the result if these and most other construction operations are taken out of the customary system of contract construction? What may we expect if the perfected system of highway construction developed by the Bureau of Public Roads in cooperation with state highway departments is to be scrapped in favor of CWA methods?

These dangers of wrongly planned working procedure threaten the welfare not alone of the construction industry but of the whole nation. It is important that they be pointed out to the President's advisers without delay, in order that the high purpose of the construction program may not be defeated by fatal error at the start—in order that the plan may aid and not set back recovery.

## Can the Highway Industry Coordinate?

AS THIS ISSUE reaches its readers the sessions of the annual convention of the American Road Builders Association will be in progress. The occasion means much to roadbuilding. Bluntly stated, unless the highway industries rally strongly to the support of the association, its outlook is bleak. Support does not mean that manufacturers must provide a great money-earning exhibition; it does mean that they together with engineers, contractors and the whole range of road transportation interests must become paying and working members. This situation was made clear in these columns a year ago. And in the twelve months that have passed nothing has occurred to change it.

During the past year the association has done more work in promoting sound highway administrative practices than for many years past. It has earned support. But it has not been supported by the industry. In fact, save in individual cases the membership of the industry has failed to coordinate its purposes sufficiently to put its money and effort behind any movement to conserve and promote its roadbuilding market. It has failed to support the American Road Builders or any other association dedicated to its interests. What is the reason?

Search for the answer goes deeper than the curtailed markets of depression. Comparatively, the roadbuilding industries have had a better buying market than have those that depend on other branches of engineering construction, and the market has come to them with less effort on their part. It has always done so. And here lies the fundamental reason for the apathy that is behind failure of the industry to cooperate in association work or in any other coordinated effort. The industry has been on the roadbuilding dole so long that it cannot contemplate any other possibility. It sees no recourse other than to stand by each year until motor-vehicle taxes and federal gifts are added up, and then to wage an internecine war for division of the windfall. The industry has never had the sales problem of creating business.

These are the bald truths behind the straitened circumstances in which the American Road Builders Association finds itself. As the only organized body representing all branches of the highway industry it deserves its support until the industry shall create and maintain an organization that better represents its activities and ambitions.

Strong association work was never more urgently needed than it is now. With experiments being undertaken in highway policies, contractual relations and traffic control, with diversion of highway funds increasing, with a taxpaying public becoming rebellious and with federal legislation resisting donations of more and more road money to replace diverted state road money, the concerted strength and wisdom of the highway interests are necessary for sound planning and execution.

If highway interests will combine, they can control their own business future and serve the people who use the public roads. To coordinate effectively, however, they need a different industrial spirit than that with which they have so far shown themselves to be inspired. Hope for the future lies in the fact that present inaction is due to lack of will and not lack of ability. The industry needs only the will to control its destiny instead of supinely accepting whatever fate politics and rival interests allot. Will it meet the demand?

# CURRENT NEWS

## New Conditions Expand Activities of A.S.C.E. Board

IN SPIRIT with the times, the board of direction of the American Society of Civil Engineers, at a meeting Jan. 15 in New York in advance of the annual meeting of the society, turned the activities of the society into new channels and laid the groundwork for increased activities in existing channels in order to increase the usefulness of the society to its members. Some of the new plans initiated are still in the formative stage and will not be announced at the present.

Most notable among the decisions made was one under which, within certain limitations, the soceity will undertake to defend members against whom unsupported charges are made as the result of which the member is removed from his position without a proper hearing. As quick action is essential in such cases, the executive committee has been empowered to determine the society's course of action in cases brought to its attention.

### Expanding activities

The board approved a recommendation of its committee on aims and activities that a program of publicity relating to the society and its operations be undertaken. It also approved a recommendation of the same committee that the society participate actively in the furtherance of the registration of engineers in states having no registration laws, also in efforts to improve existing laws that now are inadequate. It also approved aiding in the correction of current abuse of civil service regulations.

To stimulate interest of the younger members in the current work of the society, the board authorized the naming of juniors to membership on society committees in so far as practicable.

The board approved establishment of a student chapter at Utah State Agricultural College and it authorized the Engineers Council for Professional Development to proceed with the accrediting of engineering schools. The society is the sixth of the seven principal organizations represented on the E.C.P.D. to approve accrediting by the council. The summer meeting of the society is to be held in Los Angeles in early July, and the holding of quarterly meetings will be resumed by meeting in Birmingham, Ala., in the fall.

## Contract of $1,198,000 Let for Canadian Public Buildings

Contract for the construction of a new headquarters building for the Royal Canadian Mounted Police, in Ottawa, has been awarded to the firm of Ulric Boileau, Ltd., Montreal, on a bid of $1,198,000. The structure will be nine stories high and 150x190 ft. in plan. The building is a unit in the Canadian public works program.

## Beaches, Tides and Sand Dunes Discussed by A.S. and B.P.A.

Tidal action in relation to shore lines, artificial sand-dune construction and current coast-protection practice were the leading subjects of discussion at the annual meeting of the American Shore and Beach Preservation Association, held last week at Washington.

W. W. Mack, chief highway engineer of Delaware, Dover, described an original and successful effort to protect a beach highway from storm-wave attack by building fences between and inshore of the existing dunes along the beach as a means for creating an artificial dune rampart. A year's experience showed effective sand accumulation, at many points well above the fence top.

Capt. P. C. Whitney, of the U. S. Coast and Geodetic Survey, Washington, sketched the nature of tidal variation in water level in different coast regions, the variation changing type during the month at some points. These changes of level which modify the problem of wave attack, require consideration in planning beach protection. Victor Gelineau, director of the New Jersey Board of Commerce and Navigation, Jersey City, set forth in brief synopsis the requirements influencing the two major shore-protection devices—seawall and jetty or groin.

Addresses by J. Spencer Smith, president of the Association, and Major General W. M. Markham, Chief of Engineers, U. S. Army, were followed by an illustrated address by W. J. Showalter, of the National Geographic Magazine, on shore forms and characteristics.

## Hawk's Nest Case Before Supreme Court At Federal Request

THE SUPREME COURT, on Jan. 14, granted the federal government permission to file an original suit against the state of West Virginia as an outgrowth of the controversy between that state and the Federal Power Commission bearing on the commission's claimed jurisdiction over the Hawk's Nest power project on the New River in West Virginia. This action follows action taken on Jan. 7 in the federal district court of the southern district of West Virginia when Federal Judge George W. McClintic, at the request of Attorney General Cummings, dismissed the government's suit to compel the Electro Metallurgical Co. to take out a federal license for the Hawk's Nest project. West Virginia had intervened in the latter case in support of the power company's contention that its project was outside the jurisdiction of the Federal Power Commission.

The case (*ENR*, Dec. 13, 1934, p. 774) has attracted wide attention as it centered around the question of the federal government's constitutional right to require a federal license for a power project not located on a navigable river. The government held that the power company must obtain a federal license because control of the flow of the New River would affect the navigability of the Kanawha into which it empties.

## Reports on Mapping, Land Use and Minerals Released by National Resources Board

THREE of the technical sections of the report recently submitted to the President by the National Resources Board have been completed and have been released to become part of the complete report on national resources prepared by that board. Part I of the board's report, which included the general findings and recommendations with a section elaborating on planning for the utilization of natural resources, was sent to President Roosevelt Dec. 1 and reviewed in *ENR*, Dec. 20, 1934, p. 796.

The recent sections released included Part V, Report of Board of Surveys and Maps; Part II, Report of the Land Planning Committee; and Part IV, Report of the Planning Committee for Mineral Policy.

### Report on mapping

The completion of a program of standard surveying and mapping of the United States during the next ten years is recommended by the Board of Surveys and Maps. The program would require an expenditure of $117,531,000 over this period, representing an average cost of about 8c. per acre. In the opinion of the board, "A base map of the entire area of the United States is a national need."

An adequate base map "is not only a necessity for the efficient execution of federal projects, but is of vital economic importance in many state, county, municipal and private activities, thus affecting the prosperity of the whole body of our people. The urgent need for adequate maps for national defense is recognized by all. For these reasons, it is reasonable to consider the national mapping program as a 100 per cent federal project, and that the expense of the project be borne by the federal government."

The report states that out of the 3,500,000 square miles contained in continental United States, exclusive of Alaska, only 26 per cent has been adequately mapped. An additional 740,000 square miles (24 per cent) was mapped more than 40 years ago with methods and scales inadequate for present needs and about 1,500,000 square miles remain unmapped.

The total estimated cost of $117,531,000 is allotted by the board as follows:

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|---|---|
| Control surveys | $20,200,000 |
| Aerial photography | 5,540,000 |
| Planimetric mapping | 21,486,000 |
| Contour mapping | 60,722,000 |
| Reproduction | 9,583,000 |

(Continued on page 111)

# *Washington Notes*

By Paul Wooton
*Washington Correspondent*

DESPITE the President's unqualified assertion that the work relief program would be carried forward entirely by force account, it is believed that practical considerations will force a material modification of the announced policy.

While President Roosevelt discussed the $4,000,000,000 work relief fund in terms of the fiscal year beginning July 1, Congress is likely to make the money immediately available on the ground that many projects of the types mentioned by the President can be started at once.

An analysis of state laws is being made by the Bureau of Roads to determine the exact amount of legal diversion of gasoline tax money on June 18, 1934, the date of the act prohibiting diversions in excess of those authorized on that date. In most states the task is simple but in New York an extended legal study will have to be made.

President Roosevelt's declaration that the Federal Government "must and shall quit this business of relief" got a great hand from the country. The White House has been deluged with commendatory letters and telegrams. Such objection as is heard is based on the assumption that direct work for 3,500,000 persons cannot be provided within the limit of expenditure set by the President; that work relief is too expensive and that lower than the prevailing wage should not be paid.

NRA's new regional compliance machinery is functioning much better than centralized enforcement from Washington.

All public works expenditures which cannot be definitely classed as of an emergency character are carried in the regular budget this year. In the last budget expenditures in the regular establishment were cut and later supplemented out of emergency funds.

Abundant evidence is reaching Washington that the country attaches weight to the recent report of the National Resources Board which is seen as a victory for those who favor a definite plan for the development of natural resources.

Indications are that Congress will approve legislation bringing holding companies under federal regulation and that the Federal Power Commission will be given far-reaching authority over the interstate movement of power.

Work on the Arizona side of the Parker Dam site will await a Supreme Court ruling now that the state has been given until April 1 to reply to the complaint of the United States.

## New York Builders Protest Use of Day Labor in Public Works Plan

The Building Trades Employers Association of New York City has forwarded a protest to President Roosevelt against the use of day labor in the proposed $4,000,000,000 public works construction program. Day labor, according to the association, will be more costly than contract operations and its use will practically eliminate those members of the construction industry who have survived the past two or three years.

## Arthur S. Tuttle Elected President of Civil Engineers

Arthur S. Tuttle, state engineer for the Public Works Administration in New York, former chief engineer of the Board of Estimate of New York City, was elected president of the American Society of Civil Engineers in the election held recently. Formal announcement of the election was made at the opening of the annual meeting of the society on Jan. 16.

Mr. Tuttle retired from active work for the city of New York in February, 1933, after nearly 48 years of continuous service for the city and for Brooklyn. At the time he was consulting engineer to the Board of Estimate and Apportionment, having relinquished active direction of the board's engineering work in 1928. But when the PWA sought an engineer with wide knowledge of engineering in the metropolitan district to act as its representative in New York State, Mr. Tuttle's name was suggested and he accepted the new responsibilities, being appointed late in August, 1933. Meanwhile he had been serving on a special committee named by the mayor to administer relief work.

Arthur S. Tuttle

Mr. Tuttle is a graduate of New York University in the class of 1885. Immediately upon graduation he went to work for the city of Brooklyn as a rodman in the water department; subsequently he became principal assistant to the engineer in charge of water development on Long Island. In 1901 he left the city service to take charge of an engineering investigation in Hawaii, returning within a year to become an assistant engineer on the staff of the Board of Estimate.

In his capacity as chief engineer of the board, Mr. Tuttle served on numerous committees, notably the engineering committee that developed the final plan to take the New York Central tracks off the streets of the west side of the city. He represented the city in the negotiations leading up to the final working agreement.

In the American Society of Civil Engineers Mr. Tuttle has served on the board of direction 1914-16; treasurer, 1919-20; vice president 1932-33. He is a past president of the Metropolitan Section of the Society and of the Municipal Engineers of the City of New York.

## Washington Speculates on Handling of New Works Fund

*(Washington Correspondence)*

Details of the President's work program are shrouded in mystery and officials of federal construction agencies are uncertain of their share in the $4,000,000,000 fund. It is expected that a bill providing a lump sum for disbursement under Executive Order will be introduced in accordance with the President's message and may pass the House without major difficulties. Organized attempts to earmark specific projects and types of work, however, are to be anticipated in the Senate.

Washington prognosticators foresee that the new works control agency will be a coordinating group, with the identity of present agencies such as PWA, FERA and CCC preserved in much their present form. Harry L. Hopkins and Harold L. Ickes, plus one or more additional members are mentioned as likely to serve on the board.

Financing grade crossing eliminations by a special tax on gasoline and on commercial carriers has been suggested by Secretary Ickes. He declined to comment on the extent to which highways and grade crossings may be carried out on a force account basis rather than on the usual contract basis.

## Dismissal of 200 Engineers Stirs Protest in Washington

Dismissal of 200 engineers and architects of the procurement division of the Treasury Department, with additional layoffs pending, is being protested before Secs. Morgenthau and Ickes, and Administrator Hopkins by a group headed by Robert N. Sentman, president, Federation of Architects, Engineers, Chemists, and Technicians. The men came from all sections of the country to work on the public building program, it is stated, and speeded up a section of the job, being told that successful performance would lead to further work.

After being congratulated on completing their work in record time, however, they received notices that lack of funds necessitated the layoff. Officials have told them that further work rests with Congress but efforts are being made to continue the positions under a temporary allotment. The delegation was told that arrangements would be made to pay for the overtime on past work.

## South Carolina Engineers Join National Society of Engineers

The South Carolina Society of Engineers, at a meeting held at Columbia on Jan. 3, voted to affiliate with the National Society of Professional Engineers as a member state society. The present list of state member societies in the national body now includes: New York, New Jersey, Pennsylvania, Connecticut, Illinois and South Carolina.

At the same meeting the state society approved the report of its committee on registration, covering amendments to the registration law in South Carolina, which will be presented at the present session of the state legislature. These amendments would eliminate the present exemptions in the law and require the registration of all engineers who are in responsible charge of design or supervision.

# Integration of Engineering Societies Stressed at Engineering Council Meeting

INTEGRATION of engineering societies toward a more active participation in public affairs was stressed at the annual meeting of American Engineering Council, Jan. 10-12, held in Washington. The participation of engineers in the recovery program was the main theme of discussion, presented by prominent federal officials. A conference of secretaries of engineering societies was held concurrently to exchange ideas as to successful methods of organization and management.

Steps taken by the assembly include the adoption of a plan for public affairs committees in each state made up of key men from local societies and sections; a new membership plan to encourage local societies to join the council; and the raising of budget by 33 per cent to insure more effective service. Engineering employment and salaries; the raising of the status and prestige of the profession; and the building up of more accurate knowledge of trends within the profession were active points of discussion.

Convening under the chairmanship of J. F. Coleman, New Orleans, president of A.E.C., the assembly was given an account of work over the past year by Frederick M. Feiker, executive secretary. The assembly of basic data and negotiations in the promotion of engineering employment were among the principal activities reported. Fact finding included a study of the distribution of engineers in industry which paved the way for the survey of the engineering profession about to be made by the U. S. Bureau of Labor Statistics in cooperation with A.E.C. Other surveys showed the distribution of engineers and technical societies by states and the status of engineering employment in some 70 federal agencies.

### A federal symposium

The rapid expansion of engineering work of the federal government and its pending growth under the President's new work plan, made the recovery program the major topic of the assembly meetings. Trends in construction were outlined under the chairmanship of A. J. Hammond, past president of the Construction League of America. Col. Donald H. Sawyer, director of the Federal Employment Stabilization Office and former PWA Administrator, said that the private construction industry must revive the spirit of salesmanship rather than leaning so heavily upon government for its recovery. Engineers, he declared, have the responsibility of pushing forward practical projects toward an upturn in building volume.

Thomas Hibben, chief engineer, FERA, outlined construction activities of relief labor designed to make useful improvements and to keep the workers and technicians from losing their skill in idleness.

### National planning

Harlow S. Person, acting director, water resources section, National Resources Board, stated that engineers may enter the planning movement as members of planning boards and technical advisory groups as well as sharing in the subsequent design and construction. The societies, he said, should form committees to build up data and technical standards for planning.

Capt. R. S. Patton, director of the Coast & Geodetic Survey, outlined the national mapping program, calling attention to the 10-year program of the National Resources Board for completion of the topographic map of the United States.

The forthcoming survey of the engineering profession was explained by Dr. Isador Lubin, commissioner of labor statistics, whose bureau is making this study the first of its surveys of the new problem of professional unemployment. More than 100,000 questionnaires will be sent out, he announced, to provide data of immediate practical application to the problems of engineering employment, salaries, classification of engineers, correlation of college curricula to current needs, and other matters regarding which present information is scanty. If the findings warrant, he said, it may be advisable to consider the setting up of an engineering employment unit under the United States Employment Service.

### Plans for 1935

On the final day of the conference, a group of resolutions were adopted to continue and extend the work of A.E.C. through 1935 under the same officers. The following major plans were outlined:

Better coordination of activities toward the increased participation of engineers in public matters will be effected by setting up public affairs committees of the A.E.C. in each state. The setting up of state councils is not contemplated, the plan being to assemble a few key men from the local societies and sections in each state, thus providing a network of active groups hitherto lacking in the system of engineering societies.

A new membership plan promises to make the council more completely representative of the profession by encouraging local groups to join. This will be effected by a flat rate plan of nominal dues for local societies together with a provision for the joint membership of several societies sending one delegate.

Other resolutions include: continued support of the national mapping program; advocacy of centralizing federal studies of rural electrification under the Bureau of Agricultural Engineering; support of earthquake studies of the Coast & Geodetic Survey; opposition to plans for development of the Arkansas River and tributaries as proposed before the last Congress; and A.E.C. cooperation in research of certain other agencies.

## Seven Erosion Control Projects Added to Federal Program

To carry forward the federal program of erosion control, seven new demonstration projects have been established with the approval of Secretary Ickes. The projects are located in Colorado, South Dakota, New York, Arkansas, Georgia, Virginia and Oklahoma. The work will be carried out with an allotment of $910,000 from PWA funds. Work will be started on the new project as soon as the organizations can be established, according to H. H. Bennett, director of the Soil Erosion Service.

## Works Officials and Engineers Set up Joint Secretariat

At the Rochester joint meeting of the American Society of Municipal Engineers and the International Association of Public Works Officials plans were formulated looking toward the setting up of a joint secretariat with a full time staff in Chicago, contingent upon the securing of a grant of funds from the Spelman foundation to augment the regular income of the two organizations. A grant of $43,000 has recently been made for the ensuing biennium and on Jan. 11 at a meeting of the development committees of the two organizations the joint secretariat was authorized and a joint receiving and disbursing board was elected. Donald C. Stone was elected executive director and a budget of $30,700 adopted for 1935. An assistant director and a secretarial staff were also authorized at the meeting.

The suggested activities call for a broad program of services leading to the improvement of public works and municipal engineering. Included are the establishment of an information service, preparation of special reports, conduct of a program to professionalize the public service, including assistance to engineering schools in developing training programs in public works engineering, educational efforts to secure high standards, permanent tenure, engaging in research programs, taking over such work as previously conducted by the Committee on Uniform Street and Sanitation Records and the National Committee on Street Maintenance Economics, extension and nation-wide system of reporting public work and costs and the usual society activities of conventions and publications of activities.

The new joint committee, in essence the governing board, is as follows: William J. Galligan, Chicago, chairman; Charles M. Reppert, Pittsburgh; Guy Brown, St. Louis; Thomas Buckley, Philadelphia; J. E. Root, Cincinnati; Mark B. Owen, Dearborn, Mich. The joint board selected Cincinnati as the next meeting place for a joint convention to be held the first week in October.

## Progress in Sewage Treatment Discussed at New York Meeting

Sewage treatment with the aid of chemical precipitation, yielding a degree of purification comparable with that obtained by trickling filters or activated-sludge plants, as employed at the Shades Valley sewage treatment plant at Birmingham, Ala., was described by H. H. Hendon, sanitary engineer of Jefferson County before the meeting of the New York State Sewage Works Association in New York City on January 15. During the summer months chlorinated copperas is used as a coagulant. Sedimentation without coagulation is used during the winter.

Before a crowded meeting a paper on "Sewage Plant Laboratories" was read by Wellington Donaldson of New York City. A new centrifugal machine that has been developed for dewatering sewage sludge was described by J. S. Pecker, of Philadelphia.

Morris M. Cohn, of Schenectady, was elected president of the association for the ensuing year. The secretary is A. S. Bedell, Albany, N. Y.

## Three Detail Reports Made to National Resources Board

*(Continued from p. 108)*

As to the procedure and organization for carrying out this work the board finds that the "federal government now maintains in the United States Geological Survey and the United States Coast and Geodetic Survey basic mapping agencies entirely competent to carry out the board's program. The board recommends that funds necessary for control and equipment pertaining thereto in this program be made available to the United States Coast and Geodetic Survey and that all other funds be made available for use by the United States Geological Survey."

### Land planning

Recommending the development of a public policy to effect the ownership and use of land that will best subserve the general welfare, rather than private advantage, the Land Planning Committee of the National Resources Board outlined a procedure which reverses the traditional development of land in this country. A close cooperation between the federal government and the states was urged in carrying out land planning programs.

The report "takes stock of the present and probable future requirements for various products of the land and inventories of available land resources which may be used to satisfy these requirements. It points out maladjustments in present land uses and advocates public policies for correcting such maladjustments." The report of the committee to the board is in reality a condensation of a much larger report which includes maps, charts, and tabulations representing the most comprehensive body of information on land utilization and policy which has ever been prepared in this country.

With regard to reclamation, the committee recommends the following policy, based on state participation: (1) Development of a plan based on technological and economic considerations, (2) no project be undertaken until its economic feasibility or other necessity warranting its construction has been unquestionably demonstrated, (3) in case of expenditure of federal funds there should be a national, as well as a regional, benefit; and that not only farmers, but other individuals and communities benefited be required to incur obligations commensurate with these benefits and (4) such irrigation developments shall comprise an essential part of a national plan aimed at a proper coordination of the various major forms of land use.

### Mineral resources

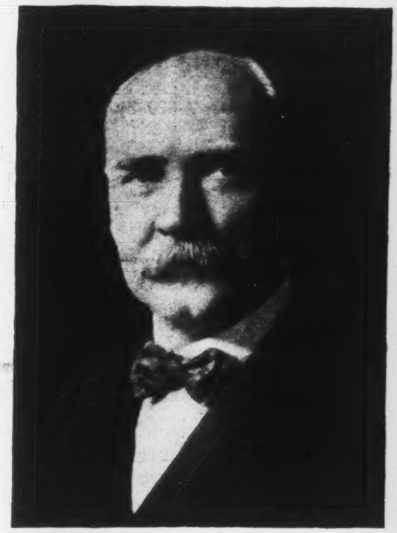
The present report of the Planning Committee on Mineral Policy is considered a preliminary statement of the major elements of the policy, containing a few definite recommendations, but without specific recommendations on many questions which are still under consideration.

Among the definite conclusions reached by the committee were: (1) Emergency provisions of the NRA code for production control should be continued; (2) in some cases, such as bituminous coal, provision for minimum and maximum prices may also be required, and (3) Congressional action should be considered in establishing of an agency to authorize control of production and capacity.

## Francis Lee Stuart Dies; Long Prominent in Railroad Work

Francis Lee Stuart, former chief engineer of the Erie and Baltimore & Ohio railroads and past president of the American Society of Civil Engineers died at his home in Essex Fells, N. J., on Jan. 15 just as the American Society of Civil Engineers was assembling in New York for its annual meeting. Mr. Stuart had been incapacitated for several months by a heart ailment.

Mr. Stuart was born in Camden, S. C., in 1866, was educated at Emerson Institute, Washington, D. C., and immediately upon graduation went to work as a rodman on the B. & O. R.R. Successively thereafter he was levelman, transitman and resident engineer until 1887 when he went to the Cahaba Coal Co. on railroad and mine development work. He returned to railroad work in 1889 and to the B. & O. in 1892 on railroad construction.



Francis Lee Stuart

In 1897 Mr. Stuart began work with the Nicaragua Canal Commission in charge of hydrographic surveys from Lake Nicaragua to the sea. Later, as division engineer for the Isthmian Canal Commission he was on the canal work until 1899 when he again returned to the B. & O. as assistant engineer on location and construction, in 1903 becoming district engineer on the low grade line improvements. The following year he was made engineer of surveys of the entire system. In 1905 he resigned to become chief engineer of the Erie Railroad which position he held until 1910 when he relinquished it to become chief engineer of the B. & O.

### Enters private practice

In 1915 Mr. Stuart resigned as chief engineer of the B. & O. and since that time has been in private practice except during the war period when he served on the War Industries Board and with the U. S. Railroad Administration. His consulting practice was chiefly in railroad rapid transit and harbor work. He also served on numerous commissions.

Mr. Stuart served as president of the American Society of Civil Engineers in 1931.

## SOCIETY CALENDAR

AMERICAN ROAD BUILDERS, annual convention, Washington, D. C., Jan. 22-25.

AMERICAN WOOD-PRESERVERS ASSOCIATION, annual meeting, New York City, Jan. 22-24.

NATIONAL BITUMINOUS ASSOCIATION, meeting, Washington, D. C., Jan. 23.

ASSOCIATED GENERAL CONTRACTORS, annual convention, Washington, D. C., Jan. 28-30.

CANADIAN CONSTRUCTION ASSOCIATION, annual convention, Montreal, Que., Jan. 29-31.

ENGINEERING INSTITUTE OF CANADA, annual meeting, Toronto, Ont., Feb. 7-8.

NATIONAL PAVING BRICK ASSOCIATION, annual meeting, Indianapolis, Ind., Feb. 7-8.

AMERICAN CONCRETE INSTITUTE, annual meeting, New York City, Feb. 20-22.

AMERICAN SOCIETY FOR TESTING MATERIALS, regional meeting, Philadelphia, Mar. 6; annual meeting, Detroit, June 24-28.

AMERICAN WATER WORKS ASSOCIATION, annual convention, Cincinnati, Ohio, May 6-10.

CONNECTICUT SOCIETY OF CIVIL ENGINEERS, annual meeting, New Haven, Feb. 19-20.

INDIANA SECTION, American Water Works Association, Indianapolis, Mar. 7-8.

CANADIAN SECTION, American Water Works Association, London, Ont., Mar. 27-29.

WEST VIRGINIA SOCIETY OF PROFESSIONAL ENGINEERS, annual meeting, Morgantown, Jan. 28-29.

KENTUCKY ASSOCIATION OF HIGHWAY CONTRACTORS, annual convention, Louisville, Feb. 9.

## *Personals*

**Gerhard F. Shafer** of the engineering staff of the Massachusetts Department of Public Works was re-elected president of the Massachusetts State Engineers' Association at the annual meeting Jan. 8.

**John E. Troy**, Belmont, Mass., has been named district engineer of the Massachusetts Department of Public Works, succeeding the late Howard C. Holden. The territory to be under the supervision of Mr. Troy includes Plymouth, Barnstable, Dukes and Nantucket counties.

**Charles F. Crowley**, former Troy, N. Y., public works commissioner, has been appointed city engineer of that city and succeeds the late Charles W. Morris.

**Earl A. Devendorf**, associate director of the division of sanitation, New York State Health Department, has been loaned to the TERA in Buffalo, N. Y., as adviser on sanitary work. The city of Buffalo is making preliminary arrangements for a $15,000,000 sewerage improvement program.

**George F. Christensen**, head of the Columbia Power & Investment Co., Stevenson, Wash., was named president of the Northwest Branch, Associated General Contractors of America, at the annual convention held in Seattle, Wash., on Jan. 8.

**J. R. West**, for several years general manager and chief engineer of the Port of Seattle, has resigned to accept a position with the Waterfront Employers of Seattle.

## *Obituary*

**August Pfafflin**, civil engineer of Evansville, Ind., and for several years city engineer and county engineer, died recently at the age of 77.

**Chester F. Dodge**, assistant professor in the department of civil engineering at the University of New Hampshire, died recently at the age of 47.

**Charles Bellamy**, who served as engineer on early railroad construction work in Wyoming and is credited as the first engineer to receive an engineering license in that state, died in Laramie Dec. 30 at the age of 83.

**Charles W. Morris, Jr.**, city engineer of Troy, N. Y., for the past six years, died Jan. 7. He was a graduate of Rensselaer Polytechnic Institute and prior to his position as city engineer had been connected with the Belmar Construction Co.

**Ernest Lyon**, for the past 30 years building commissioner of Brookline, Mass., died at his home in that city Jan. 8. He was born in Brookline 64 years ago and had spent several years in the contracting field prior to joining the city building department in 1900.

**Daniel B. Danielson**, well known contractor and engineer in the Midwest for 35 years, died at his home in Milwaukee, Jan. 11, at the age of 62. Mr. Danielson was a pioneer in the field of reinforced concrete for building construction, holding some of the early patents on the flat slab type of construction as early as 1907.

**Ernest J. Luentzel**, pioneer building contractor of Los Angeles, died Jan. 10 at his home in Montrose, Calif. He was 79 years of age. Born in Hanover, Germany, Mr. Luentzel came to this country at the age of 14 and before coming to Los Angeles 54 years ago engaged in railroad construction in Texas. He was the builder of many of the Los Angeles business structures.

**George Leonard Hosmer**, professor of geodesy and member of the civil engineering department at the Massachusetts Institute of Technology for 37 years, until his retirement last fall, died at his home in Woburn, Mass., Jan. 10 at the age of 60. He was born in Lynn, Mass., in 1874, and was a graduate of M.I.T. He became an instructor at the Institute in 1900, assistant professor in 1907, and professor in 1917. He was instrumental in establishing the summer camp of the Institute for civil engineering students in 1911, and served as its director up to the time of his retirement. In 1901 he was a member of a scientific expedition to Sumatra for making astronomical and magnetic observations during a total eclipse of the sun. Professor Hosmer was the author of several textbooks on geodesy, practical astronomy and navigation, and collaborated with Prof. Charles B. Breed, of the Institute, in the well known textbook on "Principles and Practice of Surveying." In addition to his teaching activities Professor Hosmer also had an extensive consulting practice. He served, at one time, with the U. S. Coast & Geodetic Survey.

# CONSTRUCTION STATISTICS OF THE WEEK

ENGINEERING contract awards total $24,044,000 for the week, a drop from the high volume of awards last week. Of this total, $2,118,000 represents private work and $21,896,000 public construction of which $5,139,000 is for federal awards and $16,757,000 state and municipal.

Public building awards are high for the week at $7,546,000, and highways, although below the record volume of last week, represent a good volume at $6,675,000. Other classifications are: bridges, $2,174,000; waterworks, $1,694,000; sewers, $1,041,000; earthwork and waterways, $2,073,000 and industrial buildings, $1,668,000. Commercial buildings are very low at $315,000.

The larger contracts include: Coal washing plant at Zeigler, Ill., Bell and Zoller Coal and Mining Co., Chicago; prison at Reidsville, Ga., for State Prison Commission, Atlanta, $1,081,000; state hospital, Taunton, Mass., $857,000; superstructure for parcel post building, Boston, Mass., $2,293,000; highway lettings, $528,000 by Texas; $853,000 by Illinois and $1,018,000 by Pennsylvania. In California, contracts 15 and 15A covering viaducts, grading and paving, San Francisco section and approaches, San Francisco-Oakland Bay Bridge were let for $1,173,000. The waterworks plant at Hammond, Ind., at $461,000, three levee projects in West Atchafalaya Levee District, La., at $822,000 and dredging on Calumet-Sag Channel west of Blue Island, Ill., $704,000, represent the larger projects put under contract during the week.

New capital consists of $3,073,000 in state and municipal bond sales and also a transfer from PWA financing to private financing of $2,653,000 in PWA bonds resold through the RFC.

### CONTRACTS

(Thousands of Dollars)

| | Weekly Jan. 1934 | Average Prev.4 Weeks | Week Jan.17 1935 |
|---|---|---|---|
| Federal Government | $15,532 | $4,530 | $5,139 |
| State and municipal | 14,321 | 14,248 | 16,757 |
| Total public ..... | $29,853 | $18,778 | $21,896 |
| Total private .... | 3,542 | 5,811 | 2,118 |
| Week's total..... | $33,395 | $24,584 | $24,044 |

Cumulative to date:
1934...$110,942,000 1935....$76,047,000

### NEW PRODUCTIVE CAPITAL

(Thousands of Dollars)

| 1934 | Week Jan.17 | Cumulative |
|---|---|---|
| State and municipal.. | $5,726* | $15,392* |
| PWA allotments, S&M | —2,653* | —2,569* |
| RFC loans, S&M..... | ..... | ...... |
| Corporate issues .... | ..... | ...... |
| PWA allotments, private ........... | ..... | ...... |
| Total, Non-Federal. | $3,073 | $12,739 |
| PWA allotments, Federal Constr. ........... | 1,006 | 1,836 |
| Total new capital.... | $4,079 | $14,575 |

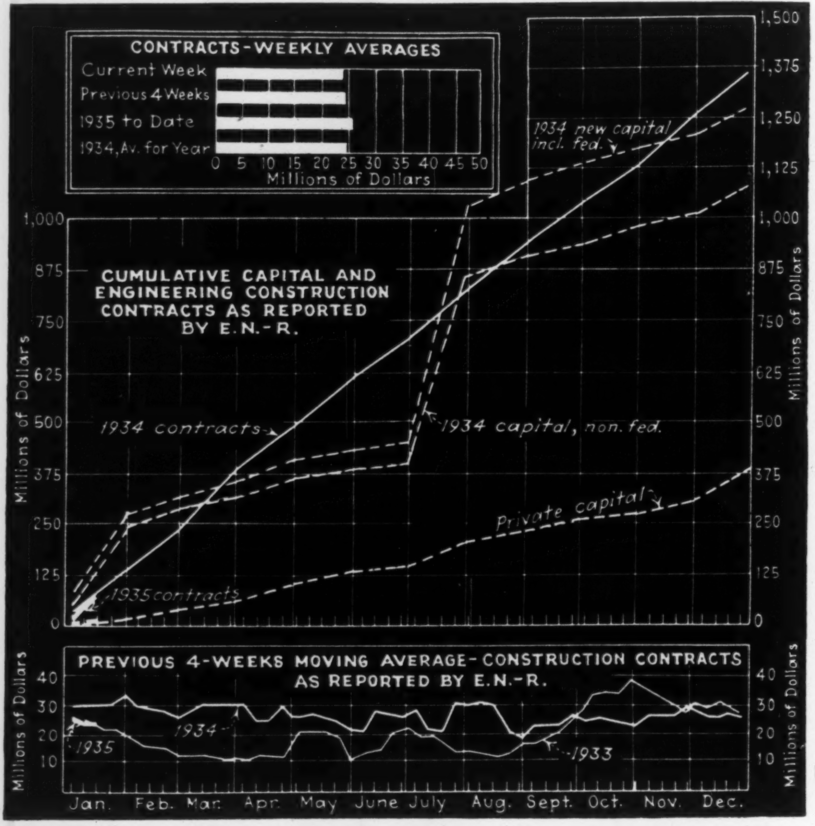
Cumulative to date:
1934...$252,573,000 1935...$14,575,000

*Sale by RFC of PWA Bonds. Not new financing but transfer from public to private capital.

**Note:** These figures include private bonds, and stocks sold for productive purposes; state and municipal bonds for construction; PWA loans and grants to states and municipalities, including the special highway funds; PWA private loans, and allotments for Federal construction.

### INDEX NUMBER

| **E.N.-R.- Cost** | **1913 = 100** | **1926 = 100** | **E.N.-R.- Volume** | **1913 = 100** | **1926 = 100** |
|---|---|---|---|---|---|
| **Jan., 1935** | **198.72** | **95.52** | **Dec., 1934** | **105** | **46** |
| Dec., 1934 | 201.86 | 97.03 | Nov., 1934 | 115 | 50 |
| Jan., 1934 | 191.26 | 91.94 | Dec., 1933 | 116 | 51 |
| 1934 (Av.) | 198.10 | 95.23 | 1934 (Av.) | 114 | 50 |
| 1933 (Av.) | 170.18 | 81.80 | 1933 (Av.) | 102 | 47 |
| 1932 (Av.) | 156.97 | 75.45 | 1932 (Av.) | 127 | 56 |



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